Annual Compendium of Aquatic Rehabilitation Projects for the Watershed Restoration Program

1999 – 2000

Watershed Restoration Project Report No. 18

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Watershed Restoration Program

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COVER PHOTO:

The Millennium Pond Project was implemented during the year 2000 to create and restore productive off-channel spawning and rearing habitat for salmonids in the Chilliwack River Watershed.

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Annual Compendium of Aquatic Rehabilitation Projects for the Watershed Restoration Program 1999 – 2000

Editor

Donna Underhill

Watershed Restoration Project Report No. 18

Watershed Restoration Program
Ministry of Environment, Lands and Parks
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Vancouver, BC V6T 1Z4

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EXECUTIVE SUMMARY

The Watershed Restoration Program (WRP) of British Columbia was implemented under the Province's Forest Renewal Plan in mid–1994 in response to a historical lack of mechanisms for ensuring rehabilitation of hillslopes, riparian areas and streams negatively effected by logging. In combination with the Forest Practices Code, WRP provides an opportunity to improve water quality and reverse fish habitat losses. This watershed–level program recognizes the "top–down" linkages of roads, gullies, and streams. Initially, between 75 and 80% of expenditures were directed at hillslopes (summarized by the Ministry of Forests). Between 20 and 25% of expenditures have been directed towards streams and these projects are reported on in this document, by the Ministry of Environment, Lands and Parks. The proportion of aquatic projects will increase over the next three years in order to meet the strategic target of Forest Renewal BC to complete restoration of 20% of the high priority or key watersheds prior to the year 2004. Funding is provided by Forest Renewal BC.

Aquatic Restoration Facts and Figures:

- Watershed sub–basin level projects in 1999/00: **108** aquatic condition assessments; **157** aquatic restoration projects (including riparian); and **22** effectiveness monitoring projects.

- Approximately **$6 million** was expended in 1999/00 on aquatic restoration works; with an average cost of **$50,454** based on **119** works projects. This is a 33% decrease from $9 million spent in 1998/99 because of reduced forest revenues during the 1999 fiscal year.

- Lead **proponents** in 1999/00: forest licensees **(64%)**, community and environmental stewardship groups **(15%)**, government agencies **(13%)**, and First Nations **(7%)**.

- As a key indicator, an estimated total of **119 km** were treated in 1999/00. This included:
  - fish access restored **(52%)**;
  - instream habitat rehabilitated and channels stabilized **(29%)**;
  - off–channel habitat restored or replaced **(19%)**.

BC Environment Region	Off–channel (km)	Instream/Channel (km)	Fish Access (km)	Totals (km)
Vancouver Island	8.7	8.0	0.0	16.7
Lower Mainland	8.5	2.1	0.0	10.6
Southern Interior	2.9	1.0	0.0	3.9
Kootenay	0.0	5.0	0.0	5.0
Cariboo–Mid–Coast	0.6	8.2	39.6	48.4
Skeena–Queen Charlotte Islands	1.4	4.7	7.0	13.1
Omineca–Peace	1.0	5.7	14.5	21.2
Total by type	23.1	34.7	61.1	118.9

- An additional total of **35 km** of riparian and bank–slope bioengineering was completed in 1999/00.

- In comparison, U.S. Forest Service averaged about **250 km per year** of restoration on federal lands (50% of Washington plus Oregon) over the past decade.

- Benefits are much broader than restored aquatic resources, and include:
  - Significant community employment operating machines, securing structures and planting;
  - Training/mentoring of 1600 people via courses, workshops and conferences since 1995;
  - A sharp increase from a few to 30 experienced stream restoration consulting firms;
  - Greater than 90% biophysical functionality of stream restoration projects;
  - Positive responses of fish stocks based on initial intensive effectiveness monitoring;
  - Positive perceptions within the forest products marketplace, supported by the recent Vancouver Marine Science Centre's *Headwaters Stream Exhibit.*

FOREWORD

Turning the Tide: Towards Recovery of Water Quality and Wild Fish Habitat in BC's Forested Watersheds

Pat A. Slaney[1]

Introduction

An Annual Compendium of Aquatic Rehabilitation Projects for the Watershed Restoration Program is a valuable technical reference for those planning, implementing and evaluating restoration of water quality and fish habitat. The descriptions of projects by restoration practitioners also provide a useful resource for public education and communication. Program planners and reviewers are provided with an equally important snapshot of aquatic restoration projects facilitated by the Ministry of Environment, Lands and Parks for Forest Renewal BC. Approximately 95% of all aquatic restoration projects (excluding condition assessments and some riparian restoration) undertaken in 1999/00 by the Watershed Restoration Program, as funded by Forest Renewal BC, are summarized in this compendium. Hillslope restoration projects are summarized elsewhere, in part as a compendium subset by the Forest Engineering Research Institute of Canada. A diverse group of proponents and their contractors including forest licensees, government agencies, First Nations, and community/environmental stewardship groups were involved in both assessment of aquatic–riparian conditions and restoration throughout the Provincial Forest in 1999/00. In 1999 Forest Renewal BC revised the goals for aquatic projects to direct funding towards the resource goal of protecting and restoring water quality and fish habitat.

Aquatic restoration, as described in the 1999/00 Compendium, is founded scientifically on several decades of research on watershed processes, limitations to salmonid production in streams, and fish habitat rehabilitation techniques. The latter are reviewed and described in the WRP Technical Circular No. 9. These techniques provide the basis for a set of integrated restorative measures to accelerate natural recovery processes in forested watersheds impaired by past logging practices, prior to the Forest Practices Code. Natural recovery of landslides would otherwise require several decades and stream channels would require up to two centuries. Success is closely associated with a watershed–scale focus, training and education initiatives, an ongoing BC–USA technical exchange with the U.S. Forest Service, and recent effectiveness evaluations. The evaluative process is attempting to achieve significant adaptive management benefits to advance the program.

The Challenge—Past Forest Harvest Practices

Today, there is much greater knowledge of the effects of past forest harvest practices on water quality, fish stock productivity and habitat of anadromous and resident fish as summarized in WRP Technical Circular No. 9 (Slaney and Zaldokas, 1997). Intensive forest harvesting activities in watersheds can alter flow and drainage patterns to existing waterbodies, as well as disrupting riparian areas. Fish passage at road culverts has also been a long–standing and universal concern, but it was not well–appreciated in the past that juveniles frequently migrate upstream for several kilometres to rear in small tributary streams, or require off–channel refuges to successfully survive periods of freshets and/or ice conditions. Also, greater sediment delivery to streams was evident; hillslope failures from old roads and the past three decades. Without intervention, old roads fail, most frequently at drainage crossings or saturated side–casts which commonly incorporated decaying woody debris and stumps. Over decades, old roads can naturally revegetate and stabilize, as reported for the coastal roads at Chapman Creek Watershed, but they can also be at risk of triggering landslides from tension cracks that can develop as old woody debris decays in some side–cast sections.

Most coastal and many interior streams were historically logged to the stream channels, accelerating streambank erosion as root masses of stumps decay. These eroding banks frequently continue to negatively effect water quality and

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reduce fish habitat until mature trees recover along riparian zones. Incremental erosion and sedimentation reduces fish stock productivity making populations less resistant to ocean regime shifts as well as fishing pressure. As a result of past riparian logging, there is a major deficit in the future supply of large coniferous wood to stream channels because existing instream wood is lost by decay at an average rate of 3% per year. Large wood is the primary structural element in forested streams, providing pool habitat, spawning gravel catchments, cover for fish rearing during summer, as well as critical refuges from floods. Although the role of large wood in streams in providing fish habitat was established earlier, the links to the natural channel–riparian process of large wood loss and recruitment was not fully recognized until the 1980s (Slaney and Martin, 1997). Past legislation tended to promote large wood removal by forest companies. Moreover, past practices by fisheries and water management agencies resulted in selective removal of logjams, compounding the problem. Moreover, channelized or uniform sections of streams are also common where streams have been historically aligned or diverted to protect logging roads, crossings, log sorting and milling sites.

Yet some impacts of logging have been less evident, have mixed effects, or only recently have been confirmed. Early forestry practices favoured natural restocking of trees. This resulted in a dominance of deciduous trees, and promoted damming activity by beavers on small streams utilized by migrant fish species. Changes in water temperatures can shift growth rates, which may shift timing of fish migration to the ocean. This can result in changes in survival rates, as suggested by studies at Carnation Creek. Finally, past land-use decisions, combined with historical over-fishing, has reduced the abundance of returning spawners, thereby reducing numbers of salmon carcasses. These carcasses are the primary source of nutrients and carbon to the stream system. This is a more subtle and under-recognized impact that is only now receiving considerable attention as declining trends in escapements of salmon become more evident throughout the Pacific Northwest. Recent tracer studies in the USA and Canada demonstrate the key role of marine-derived nutrients, even in the smaller salmon streams (Bilby, 1996). This also indicates that minimum spawning escapements must be set ecologically, to maintain trophic conditions, rather than by means of traditional spawner-recruit approaches to fisheries management.

Biological Benefits of Watershed Restoration

Case studies that examine biological benefits of watershed restoration at a watershed- or reach-level are sparse, but there is compelling evidence that selected aquatic techniques are successful. Off-channel fish habitat projects have a high incidence of success due to technical developments; typical egg-to-fry and juvenile survivals are much higher than in mainstems. Evidence supporting stabilization of logged hillslopes and channels, or restoration of large wood in streams, is largely from a few USA case studies. For example, integrated hillslope and channel stabilization at Deer Creek Watershed (Washington State) reduced sediment transport and in-filling of boulder substrates and pools. There, adult coho salmon and summer steelhead have been documented to have recovered to 50–70% of historical abundance, from a low of 10–20% a decade ago (Doyle *et al.*, 1999). Also, the effects of restoration of large wood in three debris-poor streams were monitored at Porter Creek in Washington (Cederholm *et al.*, 1998) and particularly at tributaries of the Alsea and Nestucca Rivers in Oregon (Solazzi *et al.*, 2000). There, smolt outputs increased three to five times in the treated streams compared to control streams. Similarly, densities of juvenile coho and steelhead were examined at 30 streams treated with large woody debris in coastal Washington and Oregon and strong responses were evident (Roni and Quinn, 2001). Results have been less conclusive from evaluation of 14 km of large wood restoration at a higher gradient stream, Fish Creek, Oregon, probably because coarse boulder substrates provided some habitat structure after loss of the natural supply of large riparian wood to the channel (Reeves *et al.*, 1997). More recent effectiveness evaluations of restoration projects in British Columbia are providing additional support, as documented at the West Kettle River for resident fish and Keogh River for anadromous fish. Preliminary results are summarized in this 1999/00 compendium of aquatic projects (Underhill, 2000, p. 1–17). By 2000, ongoing watershed-level treatments of the Keogh River, including road-gully stabilization, annual nutrient replacement, off-channel habitat restoration or replacement, and instream fish habitat rehabilitation, resulted in strong upward trends in the abundance and average sizes of smolts of coho salmon, steelhead trout, and Dolly Varden char, compared to an adjacent untreated watershed.

It is assumed that restoration of structural diversity and nutrient sources, often salmon or kokanee carcasses, accelerate recovery of aquatic communities and biodiversity of disturbed aquatic ecosystems. Large old growth trees, that shape alluvial stream channels with their massive rootwads as natural anchors, are the types of structural features that cannot be duplicated or replaced by restorative treatments. This is the rationale for cable-anchoring of woody complexes to streamside trees and large instream boulders, although it is well proven in the scientific literature that clusters of boulders, themselves, are prime natural habitat features of juvenile and adult salmonids. Moreover, salmon spawners

are a keystone species, functional as the vital link between aquatic and terrestrial communities, especially within the riparian zone. For long–term results, riparian restoration needs to be implemented to accelerate recovery of riparian functions, providing future desired conditions for fish and wildlife resources; shrubs and deciduous trees for leaf litter, mixed with mature coniferous trees for large wood recruitment and fluvial–resistive root systems. Riparian restoration strategies are gradually evolving as more information becomes available from modelling research on wood recruitment and loss dynamics relative to stream size. Accordingly, although projects outlined in this Compendium are focused on the short term (20–50 years), riparian projects are increasingly being focused on the long term.

Challenges to Restoration Practitioners

As watershed restoration practitioners, our challenges, other than continuity of funding, are several, if we are to advance the goals of restoration of water quality and fish habitat in historically logged watersheds:

- Collectively, we need to assure a high level of professionalism in the Watershed Restoration Program as restoration practitioners by ensuring that project activities are sharply focused on the current aquatic resource goals of water quality and fish habitat within key watersheds, and that we produce quality projects with natural features.

- Some improvements in aquatic project "quality" are needed to achieve our Program goals in the long term (>20 years), and this may require securing forest permits to obtain whole trees with rootwads, rather than logs alone:
  - use of larger wood diameter to reflect LWD diameter of mature or old-growth trees in relation to channel size (wood diameter increases with channel size); larger diameters will be effective longer, providing structure until natural recruitment of large wood initiates from riparian windfalls, streambank erosion and episodic slope failures;
  - a shift to the use of trees either with rootwads or at least re-attached rootwads is necessary to achieve objectives of restoring critical overwintering habitat;
  - there is a need to utilize whole trees with rootwads for streambank stabilization projects to ensure sufficient height to minimize erosion at flood stages.

- Some off-channel projects lack sufficient attention to "finishing" details, including rock linings of groundwater channels (chum-coho), provision of clean spawning gravels, and sufficient complex woody cover, including complex rootwads, and deep winter refuges. These project are typically improved by retaining one side as natural vegetation, as key channel or pod features, by sacrificing the other side for machine and material access.

- Bioengineering practitioners should be cautious in the use of stored cuttings; spring plantings of thumb–sized cuttings under wetter conditions have been much more effective than cuttings stored for months.

- Recent modelling of riparian supply of large wood to channels and its loss through time indicates that riparian thinning practices need to be conservative. A key conclusion is that many more stems per hectare need to be left standing where channels are small (<15–20 m) versus in larger channels because smaller large wood still contributes to LWD in smaller streams.

- Recovery of fish stocks by physical restoration alone is likely to fail, or at least be delayed, in nutrient-infertile systems where salmon stocks are highly depressed/depleted and at–risk. Nutrient replacement of depressed salmon carcasses, or nutrient restoration, is likely needed, based on recent scientific studies of the crucial role of the influx of marine nutrients in driving freshwater fish food chains (as well as salmon dependent wildlife).

Watershed restoration practitioners have little control over fish harvest rates or climatic regime shifts, both of which cause shifts in migrant survivals. Thus, recent conservative fisheries management measures in British Columbia are overdue and welcomed, particularly those that preserve stocks–at–risk, improve management of weak stocks and rebuild other stocks. These should ensure much more rapid positive responses to watershed restoration, and at a minimum, preserve stock at risk of extirpation.

Pat A. Slaney, Technical Coordination Manager
Watershed Restoration Program
Ministry of Environment, Lands and Parks

Summary of WRP stream and riparian assessment and restoration projects, by Ministry of Environment, Lands and Parks region/sub–region, which were undertaken in the 1999/00 fiscal year, whereby numbers are derived on a watershed sub–basin or tributary level.

	Channel Assessments	Habitat Assessments	Riparian Assessments	Culvert Assessments	Habitat Channel Restoration	Riparian Restoration	Fish Passage Restoration	Project Effectiveness Evaluation[1]
Vancouver Island	0	22	5	0	31	12	0	14
Lower Mainland	1	0	4	3	20	3	0	5
Southern Interior	13	2	0	2	26	0	0	1
Kootenay	1	4	0	1	12	2	0	0
Cariboo	0	6	1	4	10	3	6	0
Skeena	2	19	5	1	11	2	6	0
Omineca	2	9	0	1	4	2	3	2
Peace	0	0	0	0	2	0	2	0
Totals	**19**	**62**	**15**	**12**	**116**	**24**[2]	**17**	**22**

[1]There are two levels of evaluation—intensive and routine. Most of these projects had routine effectiveness evaluation.
[2]Only 8 are reported on in the 1999/00 Compendium.

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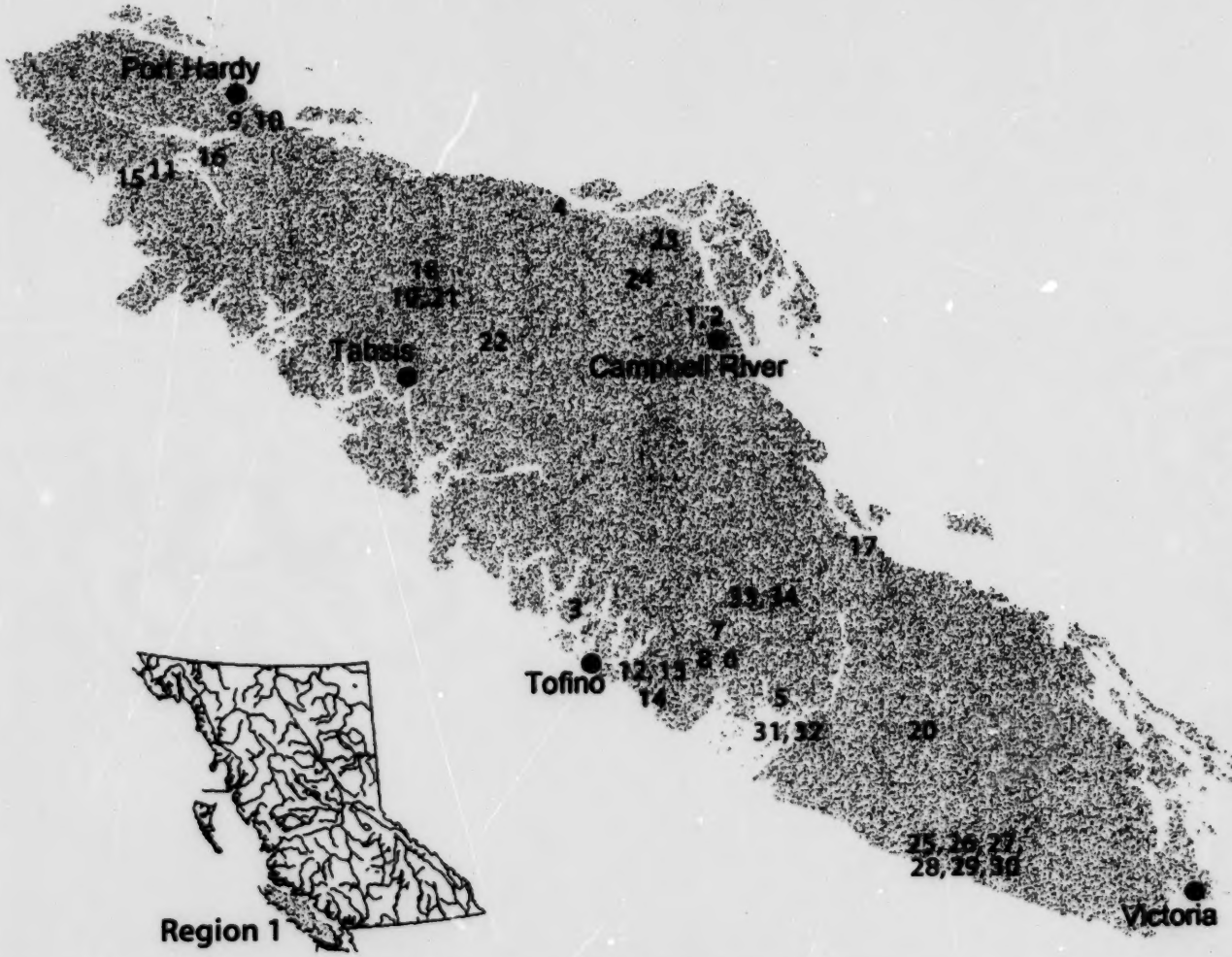

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20	Nitinat River
21	Vernon Camp Creek
22	Oktwanch River
23	Big Tree Creek
24	Spirit Creek
25	Tremblay Creek
26	Mosquito Creek
27	4–Mile Creek
28	George's Channel
29	Halliday Creek
30	Harris Creek
31	Sabrina Creek
32	Sarita River
33, 34	Taylor River

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 1, Vancouver Island.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Vancouver Island	Campbell River	Elk Falls # 3 Rearing Channel	10	5545896	338168	920-627900	00000CAMB
2		Campbell River	Raven Channel Complexing	10	5545896	338168	920-627900	00000CAMB
3		Cypre River	Cypre River Groundwater Channel Construction and Complexing	10	5462196	288082	930-368500	00000CLAY
4		Eve River	Eve River Groundwater Channel	9	5590066	695527	920-758000-11400	00000TSIT
5		Henderson Lake	Clemens Creek Groundwater Channel	10	5444809	344083	930-162500-98800	00000ALBN
6		Kennedy River	Hynds Creek Instream Restoration	10	5432050	326063	930-306400-41600	00000CLAY
7		Kennedy River	Stump Creek Side Channel	10	5451912	325846	930-306400-41800	00000CLAY
8		Kennedy River	Upper Kennedy River Side Channel	10	5444678	322380	930-306400-41800	00000CLAY
9		Keogh River	Keogh River Instream Restoration	9	5615301	616725	920-866900	00000NIMP
10		Keogh/Waukwaas Rivers	Watershed Study	9	5615301	616725	920-866900	00000NIMP
11		Klootchlimmis Creek	Klootchlimmis Creek Logjam Removal	9	5593414	594632	930-832000	00000BRKS
12		Kootowis Creek	Kootowis Creek Logging Debris Removal and Instream Restoration	10	5441122	301010	930-300800	00000CLAY
13		Staghorn Creek	Staghorn Creek Logging Debris Removal and Instream Restoration	10	5440866	310134	930-306400-11900	00000CLAY
14		Lost Shoe Creek	Lost Shoe Creek Logging Debris Removal and Instream Restoration	10	5431131	306959	930-260600	00000ALBN
15		Mahatta River	Mahatta River Instream Restoration	9	5590185	580508	930-823900	00000BRKS
16		Marble River	Howlal Creek Instream Restoration	9	5586273	615984	930-865200-42600-01600	00000BRKS
17		Nile Creek	Nile Creek Side Channel	10	5475455	381060	920-494300	00000PARK
18		Nimpkish River	Lukwa Creek Instream Restoration	9	5564269	671737	920-825900-59200	00000NIMP
20		Nimpkish River	Pink Creek Instream Restoration	9	5597985	640261	920-825900-09300	00000NIMP
21		Nitinat River	Nitinat River Side Channel	10	5392400	363733	930-071700	00000SANJ
19		Nimpkish River	Vernon Camp Creek	9	5545044	689914	920-825900-90100	00000NIMP
22		Oktwanch River	Oktwanch River Groundwater Channel	9	5529221	702902	930-511600-42100-30700	00000GOLD
23		Salmon River	Big Tree Creek Groundwater Channel	10	5568556	302439	920-725300-35500	00000SALM
24		Salmon River	Big Tree and Spirit Creeks Riparian Restoration	10	5563264	308666	920-725300-45200	00231SALM
25		San Juan River	Tremblay Creek Instream Restoration	10	5383700	407100	930-100000-12000	00000SANJ
26		San Juan River	Mosquito Creek Instream Restoration	10	5380900	400150	930-100000-05000	00000SANJ
27		San Juan River	4-Mile Creek Side Channel	10	5382600	402000	930-100000-07000-01000	00000SANJ
28		San Juan River	George's Channel	10	5383100	403700	930-100000-07000-01000	00000SANJ
29		San Juan River	Halliday Creek Instream Restoration	10	5383600	409200	930-100000-15000	00000SANJ
30		San Juan River	Harris Creek Instream Restoration	10	5382600	402000	930-100000-12000	00000SANJ
31		Sarita River	Sabrina Creek Instream Restoration	10	5418043	352704	930-110800	00000ALBN
32		Sarita River	Sarita River Instream Restoration	10	5461946	337520	930-137400-99100-99100	00000ALBN
33		Taylor River	Taylor River Groundwater Channel	10	5462657	334930	930-1374-991-991	00000ALBN
34		Taylor River	Taylor River Relic Channel Extension					

ELK FALLS #3 REARING CHANNEL

Objectives
The objective of this project is to create additional coho rearing habitat on the Campbell River by connecting a wetland to the mainstem.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Nigel Ross, R.P.F.

Proponent /Implementing Partners
International Forest Products, Fisheries and Oceans Canada (FOC).

Watershed/Stream
Campbell River

Location
The Campbell River is located on the eastside of Vancouver Island, approximately midway between the north and south ends of the Island. The Campbell River flows out of John Hart Lake and travels approximately 7 km before it empties into Georgia Strait.

Introduction
The Campbell River area has significance as a world–class fishing area. The Campbell River itself is a fairly short river but was a productive salmon producer. Since this area has been settled there has been a long history of degradation to the Campbell River. Farming and settlement occurred along the banks and the estuary was used for a variety of industrial uses (sawmills, log booming, marinas, shipyards). Mining and hydroelectric development occurred in the upper reaches. As a result of these developments productivity of the river has decreased.

Over the past 10 to 15 years there have been significant restoration activities on the Campbell River. Elk Falls #3 Rearing Channel was constructed to address the loss of overwintering side channel habitat.

Assessments and Prescriptions
Fisheries and Oceans Canada conducted the assessments and the prescriptions.

Rehabilitation Work
There was an existing wetland approximately 200 m from the mainstem of the Campbell River. The project objective was to provide access for the fish and to increase the wetted area by providing additional water to this marsh. The intake channel will be 375 m long when completed in 2000. The first 275 m were constructed in 1999 and the final 100 m will be finished in 2000. This intake will link the wetland to the mainstem of the Campbell River. Fig. 1–1 shows a view from the top of the existing wetland looking at the excavated intake channel. Large woody debris (LWD) structures were placed in the intake channel (Fig. 1–2). These structures were anchored by securing one end of the log into the bank and by placing large boulders on top and adjacent to the large woody debris.

The intake channel had cutbanks up to 3 m in height. These banks were scaled and any loose rocks were rolled down to the wetted channel edge in order to provide armouring. The banks were grass–seeded and planted with a combination of ocean spray (*Holodiscus discolor*), red alder (*Alnus rubra*), willow (*Salix spp.*) and red osier dogwood (*Cornus sericea*).

A channel was also required from the bottom of the wetland to the existing river. This channel was constructed to be 175 m long and to lose 3.2 m in elevation. A series of five "Newbury" style weirs were constructed in order to lose this elevation. Armouring was placed along the channel's wetted edge, exposed soil was grass–seeded and the area was planted with salmonberry (*Rubus spectabilis*), alder, sitka spruce (*Picea sitchensis*) and red osier dogwood.

Cost Summary
$123,637

Outputs
0.8 km of stream work
17000 m^2 of overwintering side channel habitat

Production Estimates
1,122 adult coho

Proposed Work
During 2000 the final 100 m of the intake channel will be constructed.

For Further Information

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Figure 1–1. View of the intake channel from top end of wetland.

Figure 1–2. Large woody debris structures placed within intake channel.

RAVEN CHANNEL COMPLEXING

Objectives
The objectives of the Raven Channel project are to increase salmonid habitat by adding LWD/boulder complexes.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Jesse Brown

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Interfor, Fisheries and Oceans Canada, and Forest Renewal BC.

Watershed/Stream
Campbell River/Raven Channel

Location
Raven Channel is located approximately 1.5 km upstream from the mouth of Campbell River on the north bank.

Introduction
Campbell River and side channels provide important spawning and rearing habitat for coho (*Oncorhynchus kisutch*), chum (*O. keta*), pink (*O. gorbuscha*), steelhead (*O. mykiss*), cutthroat trout (*O. clarki clarki*) (anadromous and resident), Dolly Varden (*Salvelinus malma*), rainbow trout and various coarse fish species (MELP, 2000). Campbell River is annually stocked with steelhead, coho, pink and chinook (*O. tshawytscha*). BC Hydro determined that there was a need for salmonid rearing habitat in the lower Campbell River.

Assessments and Prescriptions
The 1999 prescription created by the Steelhead Society of BC determined that in order to increase salmonid habitat in Raven Channel LWD/boulder complexes were required. These complexes were need to provide cover for all salmonids.

Past Rehabilitation Work
Raven Channel was created by Interfor in 1998. Riprap was placed under a pedestrian bridge and camouflaged riprap was placed at the mouth of Raven Channel to armour the banks against the erosion from the Campbell River. Gravel/boulder bed material was placed in the channel near the mouth to facilitate spawning.

Rehabilitation Work
Work on the Raven Channel began around June 1, 1999 and was completed on July 1, 1999.

The channel is 460 linear metres and had little to no riparian zone or LWD/boulder complexes to provide cover and temperature control for salmonids. Twenty–two pieces of LWD, 11 with rootwads, and 62 boulders were added to the channel to provide cover for all salmonids. LWD/boulders were placed in lateral and triangular complexes (Figs. 1–3, 1–4). Rootwads and LWD were transported from Roberts Lake by a Terex 235 dump truck and placed in Raven Channel by a Case 9045B excavator and a Hitachi Ex270 excavator. Further movement of the LWD/boulder complexes was done by K&D Excavation with a Cat 325 excavator.

Cost Summary

Complexing Costs	$39,937

Outputs

LWD Number	22 pieces
Boulders	62

Production Estimates
Not applicable.

Proposed Work
All prescribed work for Raven Channel was completed in the 1999/2000 season.

For Further Information

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Figure 1–3. Triangular LWD/boulder jam on the north bank of Raven Channel.

Figure 1–4. Lateral LWD/boulder jam on the southeast bank of Raven Channel.

CYPRE RIVER GROUNDWATER CHANNEL CONSTRUCTION AND COMPLEXING

Objectives
This project was designed to provide stable chum spawning habitat in the lower Cypre River, in conjunction with overwintering habitat for coho and other salmonids such as rainbow and cutthroat trout.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
John Taylor and John Ebell

Proponent/Implementing Partners
MacMillan Bloedel.

Watershed/Stream
Cypre River

Location
The Cypre River flows into Cypress Bay, approximately 15 km northeast of Tofino in the coastal temperate rainforest of Clayoquot Sound, on the west coast of Vancouver Island.

Introduction
Logging has been conducted over approximately 40% of the 60 km^2 Cypre River Watershed with most activity (26%) between 1974 and 1985 (Brown *et al.*, 1987). Logging has not occurred since 1997. Observable changes to the Cypre River that have occurred as a consequence of logging are typically related to increased bedload and associated aggradation in low gradient sections of the river (Taylor *et al.*, 1996). Loss of forest cover and road construction have modified the hydrology of the river. These changes facilitate the movement of precipitation into tributaries and the mainstem. Forty–three percent of all stream channels have been logged to at least one bank, thereby causing extensive loss of riparian vegetation and eliminating the supply of high quality LWD.

Assessments and Prescriptions
A consequence of the increased discharge and bedload during winter floods is the movement of gravels leading to disturbance and loss of mainstem spawning areas for chum salmon and possibly other species. Historically chum salmon were the most abundant species found in Cypre River and had a recorded peak density of 20,000–50,000 in 1946 and commonly achieved between 10,000 and 20,000 spawners between 1939 and 1943. Since chum migrate to the estuary shortly after hatching, they are affected directly by fluvial processes that modify their spawning areas, such as sedimentation and the lowered stability of channel morphology. Mechanical damage to eggs has undoubtedly been greatly increased by sediment transport under winter flows in mainstem spawning areas.

Past Rehabilitation Work
In 1998 restoration provided replacement refuge and rearing habitat for coho. This was achieved through construction of a groundwater–fed side channel 690 m long. Sampling in 1999 provided an estimate of 4,900 juvenile coho within the new channel, substantially higher than the predicted population size of 3,100 (Ebell and Taylor, 1999).

Rehabilitation Work
In 1999 a second groundwater–fed side channel was proposed, this time to increase the amount of protected spawning habitat for chum salmon. This channel was located among an extensive series of wetted and flowing channels within the floodplain immediately above tidal influence in the lower portion of the river.

Mel Sheng and Russ Doucet of Fisheries and Oceans Canada, Habitat and Enhancement Branch prepared the groundwater channel design. Construction was initiated on July 19, 1999.

Channel excavation was accomplished in two passes. The first pass stripped the organics and silt out of the swale, down to solid gravel (Fig. 1–5). The second pass excavated gravels down to the defined project grade (Fig. 1–6). Overall, the bank slope was maintained between 1:1.5 and 1:2. The water depth throughout the dug channel was relatively consistent, between 20–30 cm at low flows.

A dyke was constructed to provide protection from 1–in–50–year floods. This has an elevation of 15.5 m at the top, tapering to 13.7 m at the bottom. The width of the top of the dyke varied from 2 to 10 m depending on the volume of excess excavate available from the channel. The edges

were finished to an approximate slope of 1.5:1 and the dyke was topped with soil, when available, to assist with forest regeneration.

The components of channel complexing completed in 1999 were as follows:

- *Angular boulders/riprap:* In total, approximately 45 truckloads (each 15–20 cu yd) of 40–100 cm angular rocks, were used along the channel to prevent erosion resulting from spawning activity.
- *LWD cover:* Large woody debris was used primarily as cross logs to hinder the predation of adult chum, particularly by bears.
- *Artificial undercuts:* Five 4 x 3 m concrete cut banks were installed within the channel to supply refuge areas for both adults and juveniles.

At the conclusion of side channel construction the setback berm and channel sides were seeded with a clover and grass mixture.

Cost Summary

Labour	$67,639
Machinery and Materials	106,450
Total Cost	$174,089

Outputs

The completed channel, including measurement of all braids, ponds and the activation of the lower flood channel is approximately 765 m long, of which the constructed length is 515 m. The total wetted area of the channel is 3825 m^2.

Production Estimates

We estimate that this area should produce approximately 950,000 chum fry, based on the relatively conservative FOC bio–standard for chum spawning in groundwater channels (Mel Sheng, pers. comm.) This area has the potential to support over 3,000 overwintering coho juveniles primarily due to the habitat provided by the riprap. In addition, annual production of 5,000 juvenile coho might be anticipated from limited adult spawning, based on 10 females and an egg–fry survivorship of 10%.

Proposed Work

A third groundwater–fed channel is under consideration for construction in 2000. This channel would be designed to provide additional overwintering and summer rearing habitat, primarily for coho.

For Further Information

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Figure 1–5. Looking upstream after pass 1.

Figure 1–6. After pass 2 and before complexing with LWD.

EVE RIVER GROUNDWATER CHANNEL

Objectives
The objective is to increase the rearing capacity of Eve River by providing a stable groundwater channel, accessible during all flow conditions.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Karl Wilson

Proponent/Implementing Partners
Weyerhaeuser Canada, North Island Timberlands Unit.

Watershed/Stream
Eve River

Location
The Eve River Watershed, draining an area of approximately 250 km^2, enters the Adam River 5 km from Johnstone Strait. It is located on the east coast of Vancouver Island 50 km north of Sayward, BC.

The groundwater channel is located on the right bank of the Eve River, 8 km downstream of the Highway 19 bridge.

Introduction
Past logging practices negatively affected the fisheries on the Eve River like many rivers on northern Vancouver Island. Much of the mainstem and lower valley walls of the Eve River have been logged over the past several decades. The anadromous populations of chinook, coho, chum, pink and sockeye salmon (*Oncorhynchus nerka*), steelhead and cutthroat trout, and Dolly Varden char have been in decline for several decades (Summit, 1997).

Assessments and Prescriptions
Summit Environmental Consultants conducted a Level 2 Fish Habitat Assessment in 1997. The assessment indicated that fish production in the Eve River was limited by lack of rearing habitat in both the mainstem and off-channel sites. The site for the groundwater channel was identified in the Level 2 Fish Habitat Assessment. The final design work was performed in the spring of 1999.

Past Rehabilitation Work
A Sikorsky helicopter was utilized to add complexity to 1.2 km of habitat in the Eve River Watershed by placing 91 pieces of LWD into three sites during the summer of 1997.

Rehabilitation Work
The first phase of this project was to salvage fish from the channel. A Smith/Root electrofisher and minnow traps were used to remove the fish from the channel. A total of 46 coho salmon, 15 cutthroat trout and 24 Dolly Varden char juveniles were removed from the channel site prior to construction.

After the fish were removed from the construction site, a Cat 325 excavator began construction at the downstream end to the channel. At first the excavated material was sidecast along the channel. This method worked well until a seam of clay was encountered. Since the clay would not make a suitable substrate for the channel, an additional 0.5 m of clay was removed from the bottom of the channel and replaced with gravel to bring it to the finished grade. Trucks transported the clay and gravel. The gravel donor sites were connected to the channel forming deep pools, which will provide good cover for juvenile salmonids rearing in the channel (Fig. 1–7).

As the channel construction proceeded upstream it became evident that if material were sidecast along the channel a significant number of 20–30 year old coniferous trees would have to be removed. In order to maintain this riparian vegetation most of the spoil material was trucked from the channel. The soil was dumped on old unused roadways, while the gravel material was trucked to a nearby rock quarry. Trucking material from the site increased the cost of the channel considerably, but the riparian vegetation remained intact and the finished product is more visually appealing.

A berm was constructed between the channel and the Eve River to protect the channel from flooding. It was not necessary to construct a berm along the full length of the channel, as some of the land surrounding the channel was higher than the 50–year flood elevation. Material excavated from the channel was sidecast in low areas to ensure protection from flooding.

To provide cover for rearing salmonids (Fig. 1–8) and add complexity, LWD was added to the channel. Three dump truck loads of logs from the Eve River dryland sort were added to the channel, however, the majority of the LWD

originated on site. LWD was anchored by burying a portion of it into the bank. Due to low discharge volumes LWD was anchored only in the lower portion of the channel, where high flows in the Eve River could cause LWD to float out of the channel.

Boulders salvaged during construction were placed along the channel to provide cover for rearing juveniles and prevent erosion of the banks by spawning salmon (Fig. 1–8).

After the excavator completed a section of the channel, any disturbed material was seeded using a coastal reclamation mixture, followed by a top dressing of hay. The benefit of seeding immediately after the excavator has left an area shortens the time that exposed soils are subject to erosion. By the time the channel was complete, grass had germinated over half the length of the channel.

Cost Summary

The entire project cost of $92,031 was funded through FRBC. Weyerhaeuser Canada contributed $72,031 while the Steelhead Society Habitat Restoration Corporation contributed $20,000. This project provided 132–person–days of employment.

Labour	$31,939
Equipment	57,552
Administration	2,540

Outputs

The groundwater channel is 437 m long with a total area of approximately 2241 m^2.

Production Estimates

The Eve River groundwater channel should produce 896 coho smolts annually utilizing WRP biostandards of 40 smolts/100 m^2 (Koning and Keeley, 1997).

Proposed Work

It is proposed that the area adjacent to the channel will become a functioning riparian area. Future work includes thinning of a conifer stand and riparian planting along the banks.

For Further Information

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Figure 1–7. This section of the groundwater channel was the gravel donor site that is now a deep pond.

Figure 1–8. This section of the groundwater channel shows rock armouring and LWD placements.

CLEMENS CREEK GROUNDWATER CHANNEL—REFUGE POND CREATION

Objectives
The objective of this project is to augment adult sockeye holding area in the groundwater channel.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Esther Guimond

Proponent/Implementing Partners
Uchucklesaht Band and Weyerhaeuser Canada.
Project design and implementation: Resource Restoration Division, Fisheries and Oceans Canada.

Watershed/Stream
Henderson Lake/Clemens Creek

Location
Clemens Creek is located at the north end of Henderson Lake, approximately 25 km southwest of Port Alberni. The project site is located at the groundwater channel in Clemens Creek, 3.3 km upstream from the confluence with Henderson Lake.

Introduction
Previous reports indicated that logging activities in the watershed have compromised sockeye salmon production in Clemens Creek (Guimond *et. al.*, 1996 and 1997). Maintenance of the sockeye run in this system is contingent on the recovery of upslope vegetation, which will take several decades, and controlling sediment inputs into the mainstem and small tributaries.

In the short–term, the Watershed Restoration Program has funded construction of a groundwater channel in Clemens Creek to provide stable spawning and rearing habitat, primarily for sockeye salmon (Guimond, 1998a). This 'mitigation' measure will ensure escapement of sockeye fry into Henderson Lake, particularly during years of poor survival in the mainstem. In addition to this work, the Uchucklesaht Band is operating a sockeye salmon hatchery to maintain and enhance the sockeye run until the stock recovers.

Assessments and Prescriptions
Post–construction monitoring of the groundwater channel during the autumn of 1997 and 1998 indicated that predation pressure on adult sockeye in the channel was high (Guimond, 1998b). It was determined that an additional holding area in the form of a prefabricated pond could provide safe refuge for adults while also supplementing the efforts of the Uchucklesaht Band's hatchery.

Rehabilitation Work
The refuge pond is fabricated from an 18–m long, 2400–mm diameter culvert, which has been aluminized to eliminate potential toxic levels from the metal. The culvert is closed on both ends and has trap doors welded on the top for access. The advantages of this type of structure are that it is completely predator–proof, and requires minimal disturbance of channel banks and less machine–time to install. During maximum carrying capacity, water depth in the pond will be approximately 1 m at the deepest point.

Flow for the structure is derived from the existing Clemens Creek intake via a 400–mm pipeline and the groundwater channel via a 250–mm pipeline. Gate valves control both pipelines to the refuge pond. The groundwater supply originates from a 1 m^2 screened box in the groundwater channel upstream of a rock riffle. Backwatering from the riffle maintains a minimum of 15 cm of water over the intake pipe at all times. Up to 0.03 m^3/s (1 cfs) of groundwater and 0.23 m^3/s (8 cfs) of surface water can be diverted into the channel although the total sustained flow at maximum carry capacity will be approximately 0.04 m^3/s (1.5 cfs).

The refuge pond is located parallel to the groundwater channel on the west (upstream) side of the Henderson Mainline culvert (Figs. 1–9 and 1–10). This location was selected because of its proximity to the Clemens Creek 400–mm intake pipeline and the logging road, and it required the least amount of disturbance to riparian vegetation.

Cost Summary

Labour	$1,400
Materials and Equipment	54,766
Total Cost	$56,166

Outputs

The refuge pond will provide up to 43 m^2 of adult holding and juvenile rearing area.

Production Estimates

The carrying capacity of the pond is approximately 600 adult salmon.

Proposed Work

The refuge pond will be incorporated into the overall monitoring program for the groundwater channel. This includes physical and biological performance evaluations during the fall spawning season and during juvenile migration in the spring.

For Further Information

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Figure 1–9. Upstream view of the Clemens Creek groundwater channel prior to installing the refuge pond along the left bank.

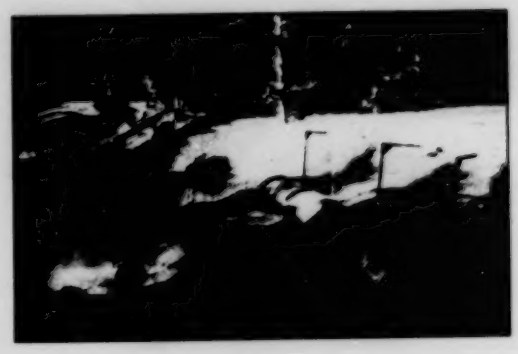

Figure 1–10. Upstream view of the groundwater channel after installation of the refuge pond.

HYNDS CREEK INSTREAM RESTORATION

Objectives
The objectives of the Hynds Creek restoration project were to address degraded habitat conditions, fragmented salmon habitat use, and declines in salmon abundance.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Mark Johannes

Proponent/Implementing Partners
Northwest Ecosystem Institute.

Watershed/Stream
Kennedy River/Hynds Creek

Location
The Kennedy Watershed is located within Clayoquot Sound on the west coast of Vancouver Island. Hynds Creek is located 1.25 km north of Kennedy Lake on the left bank of the Upper Kennedy River.

Introduction
Anadromous salmon occupy at least 300 km of streams and shorelines within the Kennedy Watershed. Of the known habitats used by salmonids in the watershed, greater than 75% of these areas (streams 135 km/shoreline 92 km) have been negatively affected by past logging practices.

Multiple salmon habitat restoration sites have been identified in the watershed. During the past five years, seven restoration projects have been completed. Three sites have been identified and restoration has been implemented for 1999. Road construction for logging and clearcutting, in combination with terrain and climate conditions, have created high sediment erosion along with frequent debris and landslide events in many higher elevation sub–basins in the watershed. Changes to riparian zone canopy cover and altered recruitment of large woody debris supplies have had considerable impact on habitat conditions and salmon production in the Kennedy Watershed.

Assessments and Prescriptions
Extensive logging in the Upper Kennedy River Watershed has led to severe deterioration of salmon spawning and rearing habitats in Hynds Creek. In Hynds Creek, high peak flows and poor riparian regrowth have eliminated large woody debris from the anadromous salmon and trout spawning and rearing habitats of the creek. Prescriptions were developed to provide more stable salmon habitats through introduction of LWD structures and scour pools.

Rehabilitation Work
Restoration activities on Hynds Creek in 1999 included the construction of four multiple LWD structures in the channel, a single compression LWD structure and two excavated scour pools along 200 m of the creek (Figs. 1–11 to 1–14).

Construction activities in 1999 included the following equipment and labour:

- 13 hours of Hitachi 200 excavator time,
- 5 hours of dump truck time, and
- 30 days of employment for seven people.

Cost Summary

Project Labour	$6,000
Equipment	2,000
Rentals, misc.	1,000
Total Cost	$9,000

Original costs were taken from a combined total for Hynds Creek and Stump Creek side channel restoration for 1999.

Outputs
0.2 km of stream was restored.

Production Estimates for 1999
Total adult salmon escapement estimates derived for Hynds Creek in 1999 were 12 coho, 6 cutthroat trout and 2 steelhead.

Proposed Work

Monitoring and limited maintenance activities are scheduled for 2000 and will include:

- monitoring of bank stability and bank revegetation success;
- monitoring and maintenance of LWD structures;
- monitoring juvenile and adult salmon habitat use.

Fourteen new restoration project sites are planned in successive years in the Kennedy Watershed.

For Further Information

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Figure 1–12. Post–restoration LWD debris jam with staff gauge installed at 0+90 m Hynds Creek (looking downstream), September 1999.

Figure 1–13. Post–restoration LWD drop structure at 0+75 m Hynds Creek (looking upstream), September 1999.

Figure 1–11. Hynds Creek pre–restoration at 1+10 m looking downstream to 0+80 m, November 1998.

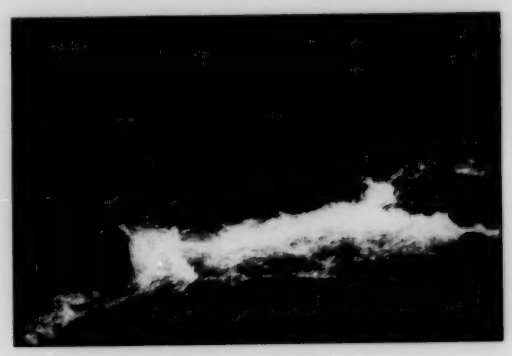

Figure 1–14. Post–restoration LWD piece and small berm at 1+05 m Hynds Creek (looking upstream), November 1999.

STUMP CREEK SIDE CHANNEL AND UPPER KENNEDY RIVER SIDE CHANNEL

Objectives
The Stump Creek side channel project was initiated to address degraded habitat conditions, fragmented salmon habitat use and declines in salmon abundance. The project developed in 1999/2000 continues from restoration work begun in 1998/99. Maintenance, monitoring and riparian restoration were also conducted on Jump–Off Bridge side channel (Upper Kennedy side channel).

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Mark Johannes

Proponent/Implementing Partners
Northwest Ecosystem Institute.

Watershed/Stream
Kennedy River/Stump Creek, Upper Kennedy River

Location
The Kennedy Watershed is located within Clayoquot Sound on the west coast of Vancouver Island. The Upper Kennedy side channel is located 2 km north of Kennedy Lake on the right bank of the Upper Kennedy River. Stump Creek side channel is located 11 km north of Kennedy Lake on the left bank of the Upper Kennedy River.

Introduction
Anadromous salmon occupy at least 300 km of streams and shorelines within the Kennedy Watershed. The habitat and salmon production values are considered high among other watersheds within Clayoquot Sound. Greater than 75% of the known salmonid habitat in the watershed (streams 135 km/shoreline 92 km) has been negatively affected by past logging practices.

During the past five years, seven restoration projects have been completed and many more have been identified. There are frequent debris and landslide events in many higher elevation sub–basins in the watershed caused in part by logging–related activities and in part by terrain and climate conditions. The changes to riparian zone canopy cover and altered recruitment of large woody debris supplies have had considerable impact on habitat conditions and salmon production in the Kennedy Watershed.

Assessments and Prescriptions
Extensive logging in the Upper Kennedy River Watershed has led to severe deterioration of salmon spawning and rearing habitats in Hynds Creek, the Upper Kennedy River side channel and Stump Creek side channel.

In the Upper Kennedy side channel, aggraded sediments have reduced habitat conditions to the point where little or no water flow exists. Discussion of 1997 and 1998 activities can be found in Zaldokas (Ed.) 1998. Final prescriptions in the Upper Kennedy side channel include riparian planting of conifers and maintenance and monitoring of past restoration works.

In the Stump Creek side channel, degraded substrate has created paved conditions across much of the 650 m channel length. This side channel experiences peak flood conditions (1:50) where discharge reaches 250 m^3/s. Restoration prescriptions are planned to develop a second ballasted LWD structure to survive peak flood conditions. It would locally support aggradation of sediments and maintain pool formation for salmon spawning and rearing.

Rehabilitation Work
Restoration activities in the Upper Kennedy side channel included 1200 m of riparian conifer planting along the channel's length and maintenance of four LWD structures and two rock riffles (Fig. 1–15). Restoration of the Stump Creek side channel included construction of a second multiple LWD structure and associated scour pool (Figs. 1–16 and 1–17). The first LWD structure was constructed in 1998. Restoration of the Stump Creek side channel will continue through a number of phases of construction in following years.

Construction activities in 1999 included the following equipment and labour:

- 27 hours of Hitachi 200 excavator time,
- 10 hours of dump truck time, and
- 83 days of employment for 15 people.

Cost Summary

Project Labour	$21,938
Equipment	5,562
Rentals, misc.	2,506
Total Cost	$30,006
Stump Creek	6,500
Upper Kennedy	23,500

Outputs

2.2 km of stream were restored.

Production Estimates for 1999

The following total adult salmon escapement estimates were derived for each 1999 restoration site:

1. Upper Kennedy River side channel—45 sockeye, 115 coho, 6 steelhead, 8 cutthroat trout;
2. Stump Creek side channel—18 coho, 4 steelhead salmon.

Proposed Work

Monitoring and limited maintenance activities are scheduled for 2000 and will include:

- data logger download and maintenance;
- monitoring of bank stability and bank revegetation success;
- monitoring and maintenance of LWD structures and rock riffles;
- monitoring juvenile and adult salmon habitat use.

Fourteen new restoration project sites are planned in successive years in the Kennedy Watershed.

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Figure 1–15. Completed conifer riparian planting and structure maintenance in the Upper Kennedy side channel.

Figure 1–16. Stump Creek side channel second multiple LWD structure.

Figure 1–17. Stump Creek side channel LWD structure with Nuu-chah-nulth Tribal Council First Nation crew members and project biologist.

KEOGH RIVER STREAM RESTORATION/DEMONSTRATION SITE PROJECT

Objectives
The objectives of the Keogh River restoration project are to restore fish habitat affected by past forest harvesting practices and to provide training to restoration practitioners on the proper techniques for assessing and restoring fish habitat and riparian conditions.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Lloyd Burroughs, Daiva Zaldokas and Pat Slaney

Proponent/Implementing Partners
Western Forest Products Ltd. (WFP), Port McNeill Division/Ministry of Environment, Lands and Parks and BC Conservation Foundation.

Watershed/Stream
Keogh River

Location
The Keogh River is located at the northern end of Vancouver Island. It flows northeast for 33 km from Keogh Lake headwaters and drains into Queen Charlotte Strait south of Port Hardy, BC.

Introduction
The Keogh River is a demonstration–training site for both applications of instream and off–channel fish habitat rehabilitation for the Watershed Restoration Program. The Keogh River lies largely in Western Forest Products Ltd. tenure (TFL 25). Over the past six years, WFP has been a partner in restoring the watershed by supplying restoration materials and undertaking road deactivation and revegetation work at most unstable road and gully sites.

Projects continue to investigate salmonid population abundances, the effectiveness of restoration structure placements, off–channel sites and stream fertilization on salmonid density growth and survival, as well as ballasting requirements for structural integrity of LWD complexes.

Assessments and Prescriptions
Overview, Level 1 and 2 riparian assessments of approximately 8.4 km of riparian reserve zone were conducted in 1999. Riparian treatments were recommended for 44 or the 63 polygons examined (total gross treatable area 18.1 ha) and about 4.5 km of rehabilitation is expected to be implemented in February to March, 2000.

Instream restoration activities in 1999 were concentrated in the lower 13 km of the mainstem Keogh River. Logged sections at Rupert Main and Hwy. 19 reaches lacking in fish habitat complexity based on a fish habitat assessment were restored.

Past Rehabilitation Work
Restoration efforts in 1996 and 1997 were concentrated along the mainstem Keogh River, between the West–80 bridge crossing and approximately 1 km downstream of Keogh Lake. In 1998, sections still deficient in habitat complexity were restored with effort put toward repairing a few structures that shifted during the floods of winter, 1997. Some structures installed in 1996 were reconfigured. Reaches restored in 1998 include Wolfe Creek, West 103 –West 104, Trib 13, West Main to West 80 and Misty 1500.

Rehabilitation Work
In 1999, a total of 121 fish habitat structures were installed requiring a total of 96 pieces of large woody debris, 26 rootwads and 723 large boulders (Figs. 1–18 to 1–21). Low–level stream fertilization continued for the third consecutive year with the addition of 1110 kg of 7–40–0 slow release briquettes at 21 mainstem and selected tributary sites. Equipment and materials used and methods undertaken are described in Zaldokas *et al.* (1999). An estimated 141 person–days of employment was created.

Cost Summary

Labour (via WFP)	$14,669
Equipment and Materials (via WFP)	53,490
MELP – UBC Labour Contribution	5,000
Total Cost	$73,159

Outputs

Structures were installed over a lineal river distance of 1.0 km creating an estimated 17259 m^2 of fish habitat.

Production Estimates

According to salmonid production biostandards for mainstem habitat complexing (Koning and Keeley, 1997), the structures installed could produce 10,183 coho smolts and 552 steelhead smolts annually. However, gradient and substrate condition are likely to largely limit the response of coho to the LWD structures versus boulder clusters. Coho and steelhead smolt production improved substantially in 1999 at Keogh River (see evaluation).

Proposed Work (2000/2001)

Further fish habitat restoration and riparian treatments (thinning, girdling, and brushing) will be implemented.

For Further Information

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Figure 1–18. Downstream view of site #45 pre–restoration of fish habitat in the Rupert Main restoration reach of the Keogh River, 1999.

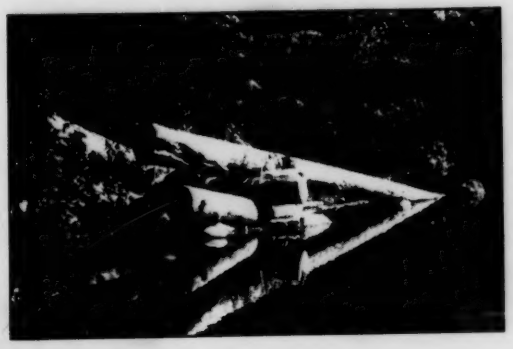

Figure 1–19. Downstream view of site #45 post–restoration of fish habitat in the Rupert Main restoration reach of the Keogh River, 1999.

Figure 1–20. Upstream view of site #26 pre–restoration of fish habitat in the Hwy. 19 restoration reach of the Keogh River, 1999.

Figure 1–21. Upstream view of sites #26–29 from site #25 post–restoration of fish habitat in the Hwy. 19 restoration reach of the Keogh River, 1999.

KEOGH/WAUKWAAS RIVER WATERSHED STUDY—JUVENILE SALMONID DENSITY AND GROWTH, 1997–1999

Objectives
The objective of this ongoing study is to determine the effectiveness of watershed–level restoration techniques (e.g. habitat creation, nutrient addition, slope stabilization) on the production and growth of salmonids in the Keogh River.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Don McCubbing and Bruce Ward

Proponent/Implementing Partners
Ministry of Fisheries.

Watershed/Stream
Keogh and Waukwaas Rivers

Location
The Keogh and Waukwaas Rivers, two fourth–order coastal streams, are at the northern end of Vancouver Island. The Keogh River flows northeast for 35 km from Keogh Lake headwaters and drains into Queen Charlotte Strait (127.4° W, 50.6° N) south of Port Hardy, BC. The Waukwaas River, 24 km in length, flows into Rupert Inlet (127°21' W, 50°35' N) near Coal Harbour, BC. These watersheds of similar climate and geomorphology drain neighbouring hillslopes that have been exposed to comparable forest practices.

Introduction
Under the auspices of Forest Renewal BC (FRBC), and in connection with the Forest Practices Code, considerable resources have and will be used to undertake Watershed Restoration Projects (WRP). One component of such rehabilitation work is the restoration of aquatic habitat through in–river treatments. In large programs such as the WRP funded by FRBC, assurance that program goals and benefits have been attained is fundamental.

Key to evaluating the success of WRP projects will be the ability to adequately measure changes in the aquatic environment as a result of the various treatments.

Assessment and Monitoring
The third year of this study assesses the effectiveness of WRP stream habitat rehabilitation techniques through instream sampling in representative treated and untreated reaches, and through comparison of results with population dynamics data gathered from 25 years of salmonid juvenile abundance instream, smolt enumeration, and adult steelhead run size estimates. In–river treatments, as stream habitat structures and slow–release nutrient applications, to the Keogh Watershed have been incrementally increased over the five–year period (McCubbing and Ward, 1997, 1998 and 1999 in prep, Zaldokas *et al.*, 1999), along with earlier road deactivation and ongoing construction of off–channel ponds and channels. Juvenile salmonid density, growth, smolt yield and adult escapement data are collated and analysed for change, in a staircase–type experimental design. To strengthen the analysis, a neighbouring watershed (Waukwaas River) is being monitored, but without WRP stream rehabilitation treatments. Data on the escapement enumeration of pink and coho salmon in the Keogh River (McCubbing *et al.*, 1999) will be added to the adult steelhead data, to further assist the evaluation of the effectiveness of WRP techniques, and to calibrate coho and steelhead smolt yield to adult escapement (i.e., smolts per spawner as a function of spawners pre– and post–treatment, Ward, 2000 in press).

Restoration Responses 1997–1999
Juvenile Fish Abundance, Standing Crop and Smolt Yield
A wide variance in salmonid abundance was found, both within watersheds and between watersheds among the three study years. These differences, where apparent, may have been the result of a combination of factors, including: habitat availability, adult escapement, juvenile mortality, and reach location within the watershed, along with environmental conditions in the year of sampling (e.g., drought low flows, winter floods, etc.).

Steelhead fry abundance in the Keogh River has been limited by low adult escapement (<100 adults) in recent years, due mainly to poor rates of survival from smolt to adult (<4%, Ward and McCubbing, 1998; Ward, 2000). Despite low adult returns a statistically significant ten–fold increase (to a mean of ~140 fry•100 m^{-1}) in steelhead fry abundance was apparent between 1997 and 1999.

Densities of steelhead parr were significantly higher in 1999 on the Keogh River (mean of 55 parr•100 m^{-1}), compared to 1998 and 1997 data (mean of 22.5 and 17 parr•100 m^{-1} respectively). In 1999, steelhead parr were in greatest abundance on the Keogh River in the reaches treated with structures and nutrient addition (45 to 126 parr•100 m^{-1}) compared to nutrient enriched–only reaches in the same river locations, (40 parr•100 m^{-1}). These densities from treated reaches in the Keogh River were greater than steelhead parr densities throughout the untreated Waukwaas River (4 to 38 parr•100 m^{-1}).

Coho fry abundance was, on average (all reaches), higher in the Keogh River in 1999 than in either of the previous sample years, increasing by an average of 53% over 1998 results to 500 fry•100 m^{-1}. Coho fry abundance on the Waukwaas River also increased over 1998 data by an average 42% to 173 fry•100 m^{-1}, but lower than that recorded in 1997.

Smolt yield from the two watersheds has been assessed for five years, including two years pre–treatment and three years partial post–treatment of the Keogh River (Fig. 1–22). Coho smolt numbers rose steadily for both watersheds through the first three years of investigation, but fell sharply in the Keogh River in 1998. A marked recovery of coho smolt yield was observed in 1999, to 53,000 fish (72% of 25–year average, McCubbing, 1999). In the Waukwaas River, the dramatic increase in coho smolt yield measured in 1998 was not sustained; yield dropped to levels that were similar to those of Keogh River in 1999. Steelhead smolt numbers had remained low and were increasingly reduced over the four–year study period to 1998 at the Keogh River. However, in 1999 smolt yield increased two–fold over 1998 to the highest on record since 1993. Substantial increases in estimated steelhead smolt yield on the Waukwaas River in 1998 were not sustained; levels fell to 1997 levels. Increases in Dolly Varden and cutthroat trout smolts were also recorded at the Keogh in the spring of 1999, for the first time in several years.

Habitat Structure Utilization

The average density of fish (no.•100 m^{-2}) from 1997 to 1999 for all structure sites and for each structure type were compared, including results for steelhead fry, steelhead parr, and coho fry. The range in mean density was broad among common structure types in 1999 (coho fry, 41 to 95 fry•100 m^{-2} Fig. 1–23; steelhead parr, 0 to 11 parr•100 m^{-2} e.g.). This was in agreement with the overall range in values observed in 1998 which were an improvement over 1997, although fish response within structure type was markedly different. Examining results from all structures across all sample years, trends emerged. Steelhead fry were most abundant in double deflector logs, and boulder clusters, whilst steelhead parr favoured double deflector logs and lateral debris jams. Coho fry were most abundant in double deflector logs and lateral debris jams, although there was much variance within this data. In all cases, yearly and within reach (same year) variations in juvenile salmonid abundance suggested that no common structure type significantly outperformed any other.

Growth and Fertilization

Summer steelhead fry weights and lengths were significantly greater in the nutrient–enriched Keogh River than in the Waukwaas River (untreated) in 1999 ($p<0.001$, t–test for both weight and length). Similar results were observed in nutrient addition–treated sections of the Keogh River in 1997 and 1998. Average weight of steelhead fry by autumn in the Keogh also exceeded that in the Waukwaas River, by over 50% (Fig. 1–24).

Growth differences in steelhead parr were more difficult to interpret as several age classes comprised the population within any reach. The age class structure also varied by reach on the Keogh River in any sample year, as a function of recruitment and the progressive treatment of nutrient addition through the watershed as well as the number of years which resident parr may or may not have been exposed to improved nutrient conditions. Abundance, size and scale age data from Keogh River smolts in 1999 (first year of a response in age 2 smolts from nutrient addition which began in 1997 over the lower half of the watershed) was used to examine the response to nutrient addition. These promising preliminary results indicated a numerical increase in smolt yield, an increased length–at–age, and decreased age at smolting compared to untreated historical data (Fig. 1–25). Initial results from whole–river nutrient addition on smolt yield are not expected until 2001.

Cost Summary

Total cost was $60,000, including $32,500 for in–river monitoring and reporting. An additional three weeks of work was undertaken by MELP staff ($7,000 included in total).

Summary

Positive effects of treatments included:

Steelhead response

- increased abundance and geographically wider distribution of steelhead fry within the watershed despite a continued low escapement of adults;
- expanded fry abundance within reaches in relation to nutrient addition;

- improved fry growth rates compared to the untreated neighbouring watershed (by 50%);
- substantially increased parr abundance (260% since treatment began) regardless of low spawner numbers;
- improved smolt yield (highest count since 1993) and larger size–at–age of smolts indicating improved growth rates of parr during their instream residence;
- evidence of a positive relationship between the complexity of the habitat structure and an increased abundance of steelhead parr.

Coho response

- the highest fry abundance since treatments started was in 1999, corresponding to adult increase;
- improved smolt yield in 1999, to 70% of long–term average regardless of low spawner numbers;
- increased growth of fry despite high densities;
- increased size–at–age of coho smolts;
- evidence of a strong association of instream fry distribution with structure placement (particularly LWD);
- significant use of off–channel habitat developments, and instream structures during winter and summer.

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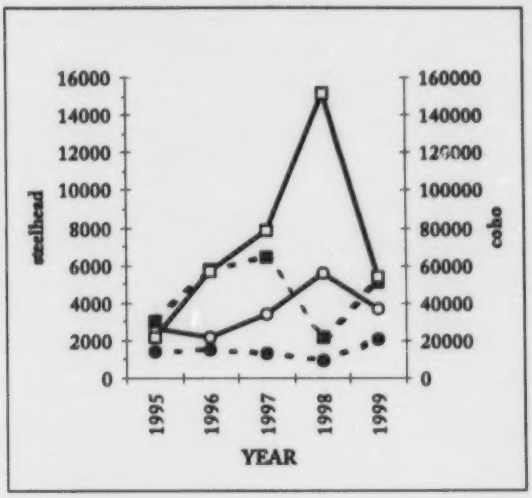

Figure 1–22. Smolt yield from the Keogh and Waukwaas Rivers 1995 to 1999. Keogh River, dashed lines and black points; Waukwaas, solid lines and open points; steelhead, circles; coho squares.

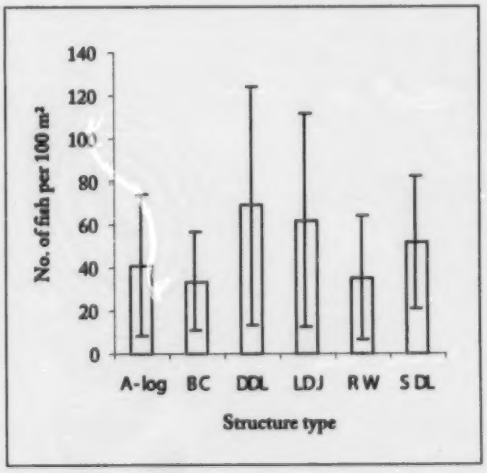

Figure 1–23. Average densities (+/– 1 S.D.) of coho fry in the Keogh River (1997 to 1999) in common habitat structure types: A–logs, boulder clusters (BC), double deflector logs (DDL), lateral debris jams (LDJ), rootwads (RW) and single deflector logs (SDL).

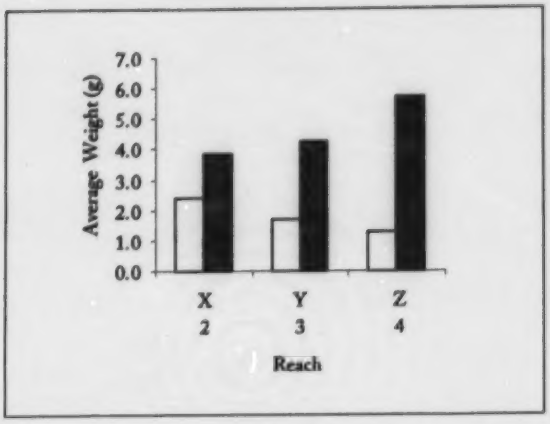

Figure 1–24. Average summer steelhead fry weight (in grams) in reaches of the Keogh River (black bars, X, Y and Z) and the Waukwaas River (open bars, 2, 3 and 4).

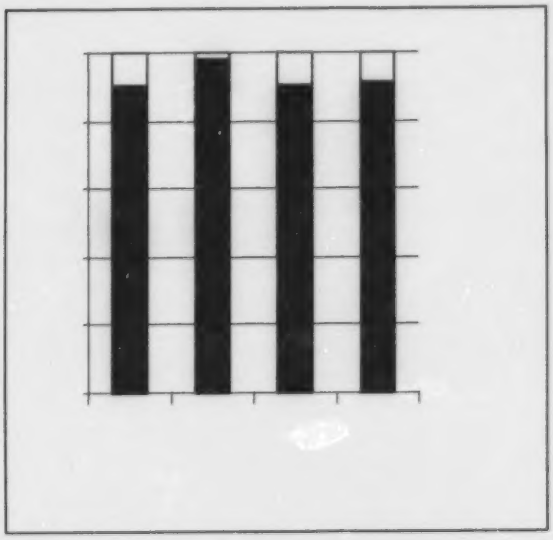

Figure 1–25. Steelhead smolt age response to nutrient addition compared to historical data (on file) and in the 1999 smolt yield: grey bars, age 2, black bars age 3, open bars age 4.

KLOOTCHLIMMIS RIVER LOGJAM REMOVAL

Objectives
The sole objective of this project was the partial removal of a large logjam near the mouth of Klootchlimmis River to improve access for returning salmon.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Bruce Walsh

Proponent/Implementing Partners
Western Forest Products Limited (WFP).

Watershed/Stream
Klootchlimmis River

Location
Klootchlimmis River is located on the north end of Vancouver Island and flows northwards into Quatsino Sound. The site is approximately 19 km northwest of Port Alice and is located near the mouth of the river.

Introduction
Klootchlimmis River drains an area of 76 km^2 and has an average slope of 2% along the lower 10 km of channel. Closer to the logjam at the mouth, the slope reduces to less than 1%. The estimated 50–yr design flow is 460 m^3/s with an estimated velocity of 4 to 5 m/s.

Over the past few decades, a series of large logjams have systematically blocked all of the main outflow channels to the estuary. Low flows were still able to pass through the logjams, but during high flow conditions, water would spill into the surrounding forest resulting in no single well–defined channel through or around the logjams.

Fish species that use the basin include chum, coho and to a lesser degree steelhead.

Assessments and Prescriptions
In September of 1997, Fisheries and Oceans Canada (FOC) requested that WFP carry out an emergency assessment of a logjam that was felt to be restricting upstream access to fish. As a temporary measure, it was decided that clearing a small 3 m wide opening through a part of the logjam would provide some improvement to access for the upcoming run.

A subsequent inspection was made in August 1998 to develop a long–term strategy for the site. It was noted during this inspection that a logjam had reformed downstream blocking the previously cleared section. The newly formed jam consisted largely of logs from the old jam that had shifted during the winter floods.

The prescription recommended that a 40 m long by 30 m wide by 3 m high section of the jam be removed (Fig. 1–26), essentially re–opening one of the main channels to the estuary. Removed logs were pulled back on to the floodplain and used as bank protection. They were fixed in place using cables attached to deadman anchors.

Rehabilitation Work
Supplies and an excavator were moved to the edge of the estuary using a barge. At low tide, the excavator was able to 'walk' to the site along the gravel bars on the edge of the main channel. Access for the work crews was gained from a mainline road 1 km to the west of the site.

The logjam was slowly dismantled working from the top down. Logs were pulled back from the channel edge, lashed together, and anchored to deadman effectively forming a large crib on either side of the bank (Fig. 1–27). The final channel width was approximately 15 m.

One problem was encountered during the removal of the logs at the bottom of the jam. Upon their removal, the flow downcut through an upstream sediment wedge, which in turn dewatered an off–channel area and stranded some resident fish. The fish were quickly gathered and transplanted to the main channel; FOC was immediately notified and later conducted a site inspection.

A significant flood in mid–November 1999 resulted in some damage to some of the completed works. Work crews carried out remedial repairs which included anchoring rootwads near the banks for erosion protection and clearing a large cross channel log which may have led to the reforming of the logjam.

Cost Summary

Labour (including consultants)	$23,880
Machinery and materials	17,070
Total Cost	$40,950

Outputs

Approximately 1200 m^2 of the logjam was removed, restoring approximately 100 m of stream. A main channel has been re–established which will improve fish access.

Production Estimates

It is difficult to estimate the production increase as a result of improving stream access, however, the project will allow greater stream utilization by returning salmon. Opening one main channel will also reduce the number of smaller side channels that become active during peak flows, which will in turn reduce fry and juvenile stranding when flows drop.

Proposed Work

Regular monitoring of the site has been recommended. Level 1 and Level 2 fish habitat assessment have not been undertaken for this watershed.

For Further Information

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Figure 1–26. Pre–construction view of the logjam near the mouth of Klootchlimmis River.

Figure 1–27. Post–construction view of the logjam removal near the mouth of the Klootchlimmis River.

KOOTOWIS, STAGHORN, LOST SHOE CREEKS—LOGGING DEBRIS REMOVAL AND INSTREAM RESTORATION

Objectives
The objective of this project was to remove and/or rearrange extensive clusters of logging debris that had blocked or reduced the usable instream salmonid habitat.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Gord Stewart, Dave Clough and Warren Warttig

Proponent/Implementing Partners
International Forest Products Ltd.

Watershed/Stream
Kootowis and Staghorn Creeks

Location
The Kootowis and Staghorn Creeks both drain the Tofino Flats area south of Kennedy Lake on the west coast of Vancouver Island. Kootowis Creek drains northwest into Grice Bay and Staghorn Creek drains northeast onto Kennedy Lake. Lost Shoe Creek drains into Florencia Bay.

Introduction
Kootowis, Staghorn Creek, and Lost Shoe are three of a limited number of low gradient streams on the west coast of Vancouver Island. Extensive forest harvesting has negatively affected these streams, severely limiting their salmonid production (FOC records). Wood debris left from the harvesting has accumulated in large debris piles in the stream channel. These piles are blocking fish access and effectively filling in the channels with wood. These debris piles have also contributed to large scale flooding of the surrounding forestlands, thereby limiting the forest regeneration to mainly scrub and willow species.

Assessments and Prescriptions
Level 1 and level 2 inventories were conducted on the watersheds in 1995 and 1996 (Clough, 1996). These inventories indicated the need to address the large instream debris build–up on 180 km of the three watersheds. Work began 1996. This initial work was assessed for effectiveness and the results used to modify the following year's work plan where necessary. The assessment reports were part of an annual winter monitoring and assessment contract.

Rehabilitation Work
In 1999 we worked on the West Fork of Staghorn Creek as well as maintenance on Kootowis Creek 1998 work areas. The rehabilitation work was conducted during the work instream window each summer. The restoration method was to remove all of the loose small wood debris (SWD) blocking the streamflow around the large wood debris and then to rearrange the LWD if necessary for the benefit of salmonid habitat. The success of the restoration was confirmed by a winter and summer assessment of the structures and habitat. The WRP Gnatt Charts were used to score the project's success. As expected the scouring caused by the new structures exposed and loosened more SWD from the streambed. This SWD was removed as a maintenance component in the following year. This maintenance allowed a training component for the crew as they had to repair any loose cables or pulled anchors.

Cost Summary

Wages	$37,889
Machinery and Materials	30,210
Total Cost	$68,099

Outputs
In 1999, 1469 m of Staghorn Creek was restored and maintenance was conducted on 5891 m of Kootowis and Staghorn Creeks that were previously restored in 1998 (Table 1). During 1999 restoration, the field crews worked on 33 debris piles removing 350 m^3 of SWD and rearranging 605 pieces of LWD along the mainstem of West Staghorn Creek and one tributary (Figs. 1–28, 1–29). Approximately 1200 m of cable were used to build the LWD structures and to anchor LWD in place.

Table 1. Restoration and maintenance areas.

Restoration Area	Length (m)
West Staghorn Creek	850
Tributary 1 (West Staghorn)	519
Other West Staghorn Tributaries	100
Total	1469

Maintenance Area	Length (m)
Main stem; Kootowis Creek	4200
Creek 1 (Kootowis Creek)*	0
Creek 2 (Kootowis Creek)*	0
Creek 4 (Kootowis Creek)*	0
Rifle Range Trib (Kootowis Creek)	841
West Staghorn Creek	850
Total	5891

*Note: No maintenance was required on these systems.

Production Estimates

The habitat improved or made accessible in 1999 has an area of approximately 3000 m^2. This area could produce 6,000 coho fry based on the FOC bio–standard of 2 fry/m^2. Cutthroat trout and chum salmon will also utilize the area. Other non–salmonid species such as stickleback (*Gasterosteus spp.*) will benefit from the new habitat. Black bears were observed capturing adult salmon in areas not previously accessible to anadromous species, just one of the project's benefits outside the "fish" realm. The reduction in forest floor flooding observed should help to return the riparian area to its natural fauna and flora. Observations over time will confirm this.

Proposed Work

There are plans to continue this project until all of the debris piles are modified in all three of the target watersheds. Currently a small portion of the Kootowis Watershed remains to be completed along with half of the Staghorn Watershed and approximately half of the Lost Shoe Watershed.

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Figure 1–28. Pre–restoration view of debris pile 1, upstream view (photo site 1).

Figure 1–29. Post–restoration view of a debris pile 1, upstream view (photo site 1).

MAHATTA RIVER INSTREAM RESTORATION

Objectives
The Mahatta River restoration project on northern Vancouver Island has been an ongoing program of Western Forest Products Limited since 1996. Part of the plan is to preserve undisturbed habitat, control in–channel sediment sources, maintain channel stability, and restore or rehabilitate fish habitat for rearing and overwintering salmonids.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Bruce Walsh

Proponent/Implementing Partners
Western Forest Products Limited (WFP).

Watershed/Stream
Mahatta River

Location
The Mahatta River flows from the south into Quatsino Sound on northern Vancouver Island. The site is approximately one hour west of Port Alice and can be accessed using the forestry road network.

Introduction
Mahatta River is located on the north end of Vancouver Island and drains an area of 122 km^2, 60% of which has been previously logged. O'Connel Lake, located approximately mid–way along the mainstem attenuates stream flow and traps coarse sediment from the upper watershed.

Historically, all five species of Pacific salmon utilized the river. Today, runs of coho, sockeye, and to lesser degree pink are supported. Steelhead and Dolly Varden are also found in the watershed.

The 50–year design flow is estimated at 475 m^3/s. The bankfull width and depth are 30 m and 3.0 m, respectively around the bend. The design velocity is 3.5 m/s and an allowance of up to 3.5 m was given for scour below the existing bed.

Assessments and Prescriptions
In the past, most of the harvesting was along on the valley bottom up to the stream edge. Because of this harvesting style, coarse sediment supply in the upper watershed has increased through related landslides and the reduction of bank strength. A natural barrier prevents anadromous fish access to the impacted upper reaches and O'Connel Lake traps and prevents coarse sediment from moving further downstream. The channel is relatively stable between the lake and the confluences of the two main tributaries. Downstream of the tributaries, however, there is significant bank erosion, bar growth and channel widening associated with sediment input from the tributaries which reduces channel complexity.

Numerous river restoration works have been completed on Mahatta River since 1996, including works on both main tributaries. During routine monitoring in 1999, significant bank erosion was noted near the Western Forest Products Limited campsite off the J Main road and was caused by flow around the sharp bend at this site. The estimated retreat of the bank is 3 m in the past year leading to the undermining of many trees and the loss of a few campsites. Also, significant quantities of coarse sediment have been released to the system from the 3 to 4 m high gravel banks.

This site had been previously identified for restoration and prescriptions had been drawn up in 1998 to control bank erosion and coarse sediment input, however, due to time and budget constraints, instream work was delayed until 1999.

Channel stability and hydraulics were assessed including flood velocities and associated scour depths. It was found that the hydraulic properties of the existing channel agreed with the general empirical relations, but given flow dynamics through the bend, channel bank erosion was expected to continue. The prescriptions for instream structures were designed to account for buoyancy, flood velocities and scour depths.

Rehabilitation Work
Three tasks were completed at this site:

1. construction of a logjam along the right bank using LWD derived from the channel (Fig. 1–30) ;

2. placement of riprap along the right bank behind the logjam; and

3. construction of a log spur further downstream also using instream LWD.

All of the structures were built using an excavator. Twelve concrete lock–blocks, buried below the anticipated scour depth, were used to anchor the logjam and the spur. Cable was used to bind the logs together and attach the structures to the anchors (Fig. 1–31).

The main feature of the logjam was a large 6 m diameter rootwad that was placed in the centre of the A–Frame shaped jam. It is anticipated that this structure will deflect flow away from the bank while at the same time promoting the formation of pool habitat for juvenile and resident salmonids at the edge of the rootwad (Fig. 1–32).

Cost Summary

Labour (including consultants)	$14,587
Machinery and Materials	16,638
Total Cost	$31,225

Outputs

Approximately 0.11 km of streambank was restored and protected from future erosion.

Production Estimates

The primary objectives of the project were not production–oriented however, following the biostandard guidelines for mainstem restoration; there will be an estimated 2.2–fold increase in stream–rearing anadromous salmonids and 1.9–fold increase in resident salmonids.

Proposed Work

Part of the prescription developed for the site included the creation of approximately 400 m^2 of off–channel habitat on the floodplain of the opposite bank.

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Figure 1–30. Downstream view showing four small LWD structures positioned to protect a steep eroding gravel cutbank. The left structure is 2 m high at the bank.

Figure 1–31. Constructing a large logjam on the Mahatta River. Logs are cabled across the structure to stiffen the logjam.

Figure 1–32. Upstream view of the Mahatta River showing two large logjams constructed to protect a gravel cutbank from erosion. A scour pool 20 m long by 12 m wide by 3.5 m deep has formed between the two logjams.

HOWLAL CREEK INSTREAM RESTORATION

Objectives
The objectives of this project were to provide greater channel stability and to increase the amount of fish habitat in the lower reach of Howlal Creek.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Northwest Hydraulic Consultants Ltd. (nhc)

Proponent/Implementing Partners
Western Forest Products Limited (WFP).

Watershed/Stream
Marble/Howlal Creek

Location
Howlal Creek is located within the Marble River Watershed and flows into Benson River, which in turn feeds in to the south end of Alice Lake. The site is located approximately 36 km south of Port Hardy.

Introduction
Howlal Creek drains northwards towards Alice Lake and has a basin area of 988 ha. It is estimated that 83% of the forests in the basin have been harvested to the streambanks with most of the harvesting occurring in the last 20 years. The stream supports all ages of coho, rainbow and cutthroat trout, and Dolly Varden.

Typical channel width is 10 m with an average slope of 2–3%. The estimated 50–year design flow adopted for Howlal Creek is 60 m^3/s, corresponding to peak velocities in the order of 3 to 4 m/s, depending upon the location in the channel. Both design estimates and field observations suggest that flow depths of 0.6 m are not uncommon.

Assessments and Prescriptions
Howlal Creek is part of the watershed restoration plan of Western Forest Products TFL 6. LGL Ltd. completed a Level 1 Fish Habitat Assessment and Level 2 Fish Habitat Prescriptions of the Marble Watershed for the MELP. WFP requested that nhc review these prescriptions and develop construction details. The overall goal was to increase the area of stable riffle, deepen existing pool habitat, increase the amount of pool cover, and to provide bank stabilization through the placement of LWD.

Rehabilitation Work
Restoration works were completed along the lower 700 m of the stream and included the construction of single rock riffle, the enhancement of six others, numerous LWD structures, and the creation of a side channel.

The newly constructed riffle was 13 m long by 10 m wide and composed of rock with a median diameter of 0.8 m. It was built with an upstream slope of 4:1, a downstream slope of 15:1 and was keyed in to the bed approximately 0.5 m and 1.5 m into the banks. Downstream of the new riffle a pool was excavated. The exact riffle location was chosen so that its backwatering effects would deepen existing upstream pools.

To enhance existing riffles and to function in combination with LWD structures, boulder (0.8 m diameter) placement was incorporated in the prescriptions (Fig. 1–33). Riffle enhancement will aid in the aeration of the flow as well as provide easier upstream passage for fry. Boulder placement in combination with the LWD structures will help to redirect the flow thereby either increasing local scour potential or reducing bank erosion.

Eighteen small LWD structures were built along the channel using both logs and rock anchors (Fig. 1–34). Approximately one quarter of the structures were built using materials sourced on site, primarily from stringers of a bridge deactivated near the upstream end of the reach. Further enhancement of each structure was made using small woody debris found on site. Structures were placed to increase available fish habitat, while at the same time reduce bank erosion. The structures generally consisted of two or three large logs (diameter = 0.6 m) anchored with up to six large boulders. Epoxy was used to attach the cable to the rock anchors.

A short 100–m long section of side channel was excavated to provide rearing habitat for juveniles. LWD was placed in the channel to add complexity.

Cost Summary

Labour (including consultants)	$38,165
Machinery and Materials	39,008
Total Cost	$77,173

Outputs

Restoration works both in the stream and along the streambanks were completed in a 700 m length of channel as well as the creation of 100 m of side channel.

Production Estimates

Following the biostandards guidelines it is estimated that there will be a 1.8–fold increase in coho productivity and an average of a 1.9–fold increase in resident salmonid productivity as a result of increasing the habitat complexity of the mainstem. An estimated 200 m^2 of side channel was created, which the guidelines predict will provide habitat for 12.2 adult coho. The side channel will also provide protection from peak flows as well as stable overwintering habitat for rearing juvenile salmonids.

Proposed Work

No further instream work is proposed although it was recommended by LGL Ltd. that a bridge approximately 275 m from the mouth be replaced as it is constricting the channel and causing aggradation immediately upstream.

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Figure 1–33. Post–construction view of a boulder enhanced riffle.

Figure 1–34. Post–construction view of a LWD structure with small woody debris enhancement.

NILE CREEK SIDE CHANNEL (ALLAN CHANNEL)

Objectives
Due to the unstable nature of Nile Creek the side channel was constructed to provide stable spawning and rearing habitat for salmonids.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Jesse Brown and Karl Wilson

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Nile Creek Enhancement Society, Fisheries and Oceans Canada, Forest Renewal BC, Ministry of Transportation and Highways, and BC Hydro.

Watershed/Stream
Nile Creek/Allan Channel

Location
The project is located near the community of Bowser on Vancouver Island, approximately 15 km north of Qualicum Beach.

Introduction
Nile Creek provides important habitat for cutthroat trout (anadromous and resident), steelhead, chum, coho and pink salmon (MELP, 2000). Since, 1983 Nile Creek has been stocked with coho fry and cutthroat trout from the Big Qualicum Hatchery (Diederichs, pers. comm., 1999). Nile Creek is subject to flash floods, erosion, severe scouring, gravel shifting and low flows prior to spawning (Hancock and Marshal, 1985).

Assessments and Prescriptions
The 1999 assessment of Nile Creek determined that there was a need for spawning and rearing habitat that would remain stable when the creek experienced significant events, such as flooding. The prescription developed by the Steelhead Society Habitat Restoration Corporation and other stakeholders recommended that a side channel be created near the mouth of Nile Creek. The channel was to extend south from Nile Creek for 1 km, with a width of 10–15 m and contain 60–80 pieces of LWD. The side channel will provide significant spawning and rearing habitat for all salmonids in Nile Creek. Allan Channel provides protection from the severe scouring and gravel shifting that regularly occurs in the mainstem.

Past Rehabilitation Work
Nile Creek has had no previous WRP work.

Rehabilitation Work
Construction in the Nile Creek side channel began on September 7, 1999 and was completed on September 27, 1999.

A pond/channel complex was created abutting Nile Creek, near its mouth, and extending south into the surrounding second growth forest. An intake manifold with trash bars (10 cm apart) was placed in Nile Creek and connected to a 150–mm pipe, which supplies the pond/channel complex with water (Fig. 1–35). The pipe extends 6 m through a berm and into the pond/channel complex. The pond is 10 m by 50 m wide with a depth up to 2.5 m. The pond contains approximately 10 pieces of LWD and the bed material is gravel/boulder salvaged from the channel excavation. The channel extends 1000 m south of the pond and flows under an existing road, where a culvert was placed. The channel is 10–15 m wide by 2 m deep and contains approximately 60 pieces of LWD (Fig. 1–36). Gravel and boulders recovered from the excavation were used to line the channel and face the berm. The excavation required 128 hours of working time from a Cat 315 excavator.

Cost Summary

Labour	$15,000
Equipment and Materials	100,174
Total Cost	$115,174

Outputs

Length	1.0 km
Pond Area	500 m^2
Channel Area	12500 m^2
LWD Number	70 pieces
Spawning Gravel	1700 m^2

Production Estimates

It is estimated that the off–channel development will result in approximately 5000 coho smolts, 1250 steelhead smolts and up to 1 million chum fry (Koning and Keeley, 1997).

Proposed Work

All work scheduled for Allan Channel was completed in the 1999/2000 season.

For Further Information

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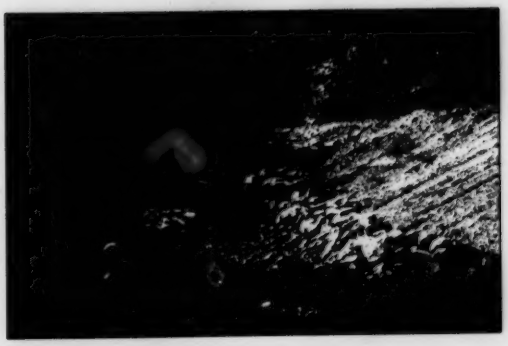

Figure 1–35. Intake from Nile Creek on the Allan Channel side.

Figure 1–36. Allan Channel with LWD placements.

LUKWA CREEK INSTREAM RESTORATION

Objectives
The Lukwa Creek instream restoration project has concentrated on restoring the stream channel morphology and access to off–channel habitat.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Northwest Hydraulic Consultants Ltd. (nhc), Alby Systems Ltd. and C.J. Forest Engineering/Canfor

Proponent/Implementing Partners
Partnership of Canadian Forest Products Ltd., 'Namgis First Nation and International Woodworkers of America (IWA).

Watershed/Stream
Nimpkish River/Lukwa Creek

Location
Lukwa Creek flows south to enter the Nimpkish River approximately 1 km upstream of the town of Woss.

Introduction
Lukwa Creek is 13 km long and drains an area of 54.4 km^2. Lukwa Creek flows through a moderately broad valley with few large tributaries and valley side slopes that quickly steepen away from the main channel. As a result most of the fish producing area is in the mainstem of Lukwa Creek. Lukwa Creek's only major tributary, Hoomak Creek, enters the stream in Reach LU3 where the Lukwa valley joins the main Nimpkish valley.

Lukwa Creek has been a significant contributor of salmonid production to the Nimpkish River system. It supports resident rainbow (that may actually be juvenile steelhead) and cutthroat trout, Dolly Varden char, and in the past has had significant runs of coho salmon.

Assessments and Prescriptions
Forest harvesting in the Lukwa basin began in the 1940s. To date approximately 42% of the total basin area has been harvested, which likely increased flood peaks in the late 1970s and early 1980s (nhc and Alby, 1998).

Lukwa Creek also experienced an increase in coarse sediment supply, both from road failures and torrented creeks. Reaches LU4, LU5, LU6 and LU7 are aggraded by coarse, angular material that has filled pools and buried substrate reducing spawning success and blocking access to off–channel habitat.

The Level I Assessment of the watershed identified the principal limitations to fisheries production as reduced adult escapement, sediment deposition that has altered streams and limited spawning success, and reduced rearing capacity for both anadromous and resident species (nhc and Alby, 1998).

Recently, the beaver dam near the outlet of Hoomak Lake was abandoned and breached. This has allowed a portion of the 3600 m^2 pond to drain and subsequently dry during low summer flows, degrading the value of the habitat by increasing water temperatures in the shallower water.

Rehabilitation Work
The following is a summary of the works undertaken during the 1999 construction window. For a more detailed discussion see nhc and Alby, 1999a.

LU6DJ1, LU6DJ2, and LU6DJ3 (LWD Jams)
The main habitat objective at these sites was to rearrange LWD to encourage further deposition on vegetated bars, trapping the coarse sediment already deposited there (Fig. 1–37). As part of the work, a crew:

- removed portions of the jams to prevent overtopping and remobilization of the coarse sediment;
- added LWD parallel to the flow along the edge of bars to prevent flood waters from crossing the bar;
- constructed LWD spurs to protect bank from further erosion (Fig. 1–38) .

HO1DJ1 (LWD Jam)
The main habitat objective at this site was to rearrange LWD to ensure access into Hoomak Creek. As part of the work, a crew:

- removed the right bank portion of the jam.

HO1BD1 (Beaver Dam)
The main habitat objective at this site was to ensure access into Hoomak Lake and beaver pond below the lake while deepening the pond. As part of the work, a crew:

- constructed 1 rock riffle from local bed material to pond water upstream;
- constructed a LWD step at the abandoned beaver dam that provided access while increasing the depth in the beaver pond.

Labour crews with hand tools completed these projects.

Cost Summary

Crew labour (8 members)	$19,280
Consultants	6,158
Other Costs	4,884
Total Cost	$30,322

Production Estimates

The rearrangement of the LWD jams will trap approximately 750 m^3 of coarse substrate, preventing migration and deposition on spawning habitat.

Using a conservative factor of 1.5 fish/m^2 it is estimated that the increased pond depth and area in HO1BD1 will provide rearing for up to 2700 (1.5 x 3600 x 0.5 m^2) juvenile coho and resident trout.

We suggest using a conservative multiplication factor of 0.65 fish/m^2 to calculate the production benefits from scour pools created by mainstem structures. Final pool measurements will be made during monitoring surveys.

For Further Information

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Figure 1–37. Downstream view of typical coarse sediment accumulation in Lukwa Creek, reach LU6.

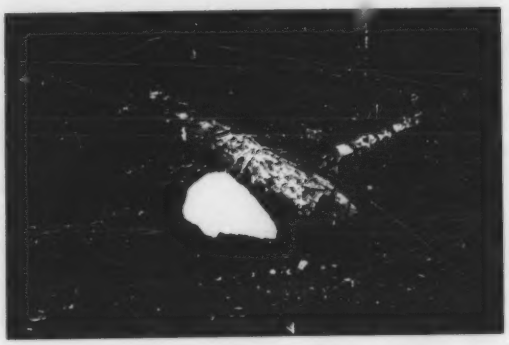

Figure 1–38. Hand–built triangular LWD spur on the right bank of Lukwa Creek.

PINK CREEK INSTREAM RESTORATION

Objectives
The objectives of this project in the lower section were to restore low and moderate flows to one channel on the fan, preventing mainstem drying and the stranding of juvenile fish in the many flood channels as the high flows recede. In the upper section the objective was to add LWD to create local scour pools and instream cover.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Northwest Hydraulic Consultants (nhc), Alby Systems Ltd., C.J. Forest Engineering, Canadian Forest Products Ltd.

Proponent/Implementing Partners
Partnership of Canadian Forest Products Ltd., 'Namgis First Nation and International Woodworkers of America (IWA).

Watershed/Stream
Nimpkish Lake and Nimpkish River/Pink Creek

Location
Pink Creek flows southeast into Nimpkish Lake near its outlet to the lower Nimpkish River. The lower or north end of Nimpkish Lake lies 8 km southeast of the town of Port McNeill on northern Vancouver Island.

Introduction
Pink Creek is a small 16.4 km^2 basin with a mainstem length of 6.6 km. The basin area occurs in MacMillan Bloedel's TFL 39 (9.6 km^2, 67.1%) and in Canfor's TFL 37 (6.8 km^2, 32.9%). The project sites occur in the lower reaches of the stream and have an average gradient of 1.5%. Pink Creek has four steep tributaries that drain portions of the steep Karmutzen Ranges to the south.

Pink Creek has supported healthy coho, pink, sea run cutthroat trout, rainbow trout, and Dolly Varden char populations in the past. It is suspected to have supported runs of steelhead and sockeye salmon. As the only known pink salmon producing tributary to the Nimpkish River, Pink Creek is very important to the biological diversity of the basin (nhc and Alby, 1999a).

Assessments and Prescriptions
Logging began in the 1930s and to date approximately 48% of the basin area has been harvested.

The oldest air photos of this area (1940s) show a very large slide in the first right bank tributary. This slide originates in a high elevation forested area and runs out over 1 km of the tributary. Inspection of post-harvesting photos also identified the destabilization of the second right bank tributary and several gullies near the drainage divide.

Aggradation in reach PK2 has led to a situation where high flows escape the main channel while low flows dry the main channel. High flows flood the road and spread over the fan. Juvenile salmon that follow the flood flows out of the main channel are trapped and killed when flows drop and the ephemeral channels dry.

Upstream from the fan, logging has resulted in poor LWD recruitment and increased gravel transport. This has lead to sediment accumulations on bars, few pools and bank erosion.

Rehabilitation Work
The restoration project in reach PK2 of Pink Creek was composed of two distinct sections, the lower 400 m of aggrading channel on the fan and the upper 500 m of large woody debris (LWD) and pool deficient channel.

The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby, 1999c.

Lower Mainstem
(Excavation, 0+188 to 0+392 m)
The main habitat objective at this site was to restore low and moderate flows to the main channel while maintaining year round flow in the right bank channel by excavating the main channel below the permanent water table (Fig. 1-39). As part of the work, a crew and equipment:

- excavated approximately 1300 m^3 of sediment from the main channel between 0+188 to 0+392 m;
- constructed 5 upstream-V LWD steps to control the grade;

- constructed bank armour and added cover;
- constructed an inlet to the right bank channel that controls the relative discharges in the right bank and main channels;
- constructed 254 m of offset berm along the right bank, using excavated material, to prevent flows from inundating the entire fan and prevents juvenile stranding.

Upper Mainstem (LWD Addition and Bar Removal, 0+392 to 0+915 m)

The main habitat objectives at this site were to rearrange sediment stored on bars to prevent remobilization and add LWD to promote local scour, protect eroding banks and provide cover. As part of the work, a crew and equipment:

- pulled–back 1100 m^3 from 11 point, lateral and mid–channel bars;
- constructed 22 LWD spurs to protect eroding banks, promote local scour and provide cover;
- constructed five LWD jams to promote local scour, provide cover and deflect flow where simple spurs were inadequate;
- constructed 17 m long rootwad crib to reconstruct a low right bank;
- excavated a 36 m^2 alcove pool along the right bank to provide winter refuge habitat and added cover.

Construction Cost Summary

Crew labour (8 members)	$27,792
Consultants	8,876
Heavy Duty Equipment	66,985
Other Costs	7,040
Total Cost	$110,693

Production Estimates

The anticipated improvements to substrate could increase viable spawning capacity by up to 200 pairs of adult coho or 400 pairs of pink salmon based on one pair of coho for every 10 m^2 or one pair of pinks per 5 m^2 of stable channel created.

Approximately 25000 m^2 of fan area and flood channels have been blocked by the offset berm. Using a factor of 1.5 fish/m^2 we anticipate a savings of 37,500 fish yearly in this system.

We suggest using a conservative multiplication factor of 0.65 fish/m^2 to calculate the production benefits from scour pools created by mainstem structures. Final pool measurements will be made during monitoring surveys.

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Figure 1–39. Downstream at the excavation through the fan, original bed level was below logs on right bank.

NITINAT RIVER—TSUK-SI-TAY SIDE CHANNEL

Objectives
The Caycuse River is a high energy system with little opportunity for salmonids to find refuge during high flood events. By developing a side channel in the floodplain of the Caycuse River, stable off-channel rearing and spawning habitat for coho, chum, steelhead and cutthroat trout will be increased.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Deborah Epps

Proponent/Implementing Partners
Weyerhaeuser (formerly MacMillan Bloedel).

Watershed/Stream
Nitinat River/Caycuse River

Location
Caycuse River drains into the head of Nitinat Lake on the southwest coast of Vancouver Island. The side channel is located on the west side of Nitinat Lake, south of the Ditidaht First Nation Reservation.

Introduction
The majority of the Caycuse River tributaries entering the mainstem are inaccessible to salmonids due to gradient barriers. The Caycuse valley is also very entrenched, preventing the formation of any off-channel habitat. The flow velocities in the Caycuse River Watershed are too high to allow for cost-effective rehabilitation within the stream channel. Opportunities to improve fish habitat with the goal of rebuilding reduced fish stocks in the Caycuse River were limited to the floodplain.

Assessments and Prescriptions
During spring of 1998 an overview assessment (FHAP) was conducted on the Caycuse and Campus Creeks, two main tributaries within the lower Nitinat River. This assessment, along with initial field reconnaissance, indicted that the highest priority for instream restoration would be through off-channel habitat within the Caycuse River.

During summer of 1998, a side channel site was selected, and test pits were installed for monitoring substrate materials and low water levels. The findings of the test pits were excellent, with good substrate and sufficient groundwater. The design for the groundwater channel were prepared by Mel Sheng and Russ Doucet, Fisheries and Oceans Canada, Habitat and Enhancement Branch.

Rehabilitation Work
The mainstem of the side channel is 1145 m in length, the upper spur is 90 m and the lower spur is 145 m for a total length of 1380 m (Figs. 1–40 , 1–41). Average channel width is approximately 7 m, giving the channel a surface area of 10065 m^2. Depths in the channel range from 0.3 to 1.2 m in the pools.

There are approximately 500 LWD pieces within the entire channel length and 1200 m^3 of rock. The rock was placed along the toe of channel, to help avoid bank erosion from spawning chum, and to provide rearing habitat for coho fry. Cement slabs were installed at five sites in the channel to provide cut bank habitat (Fig. 1–42). Two rock riffle structures were built within the main side channel to maintain water levels.

The channel banks and any disturbed areas were seeded and planted to prevent erosion and sediment input.

Cost Summary
Habitat Restoration and Salmon Enhancement Program (HRSEP)	
Forest Renewal BC	$128,045
HRSEP	60,000
MB private	20,000
FRBC (RAMS)	8,000
Total Cost	$216,045

Production Estimates
Predicted coho smolt production is about 10,065 smolts. Consequently if there is a 2% survival rate (presently low due to poor ocean conditions) from smolts to returning adults, we should see approximately 200 coho adults return to the channel.

The channel is also predicted to produce chum salmon, with approximately 300 chum fry/m^2 of useable spawning beds. The area of useable spawning beds will not be known

until chum begin to spawn within the channel, however a rough estimate of 500 m^2 of spawning habitat would produce 150,000 fry. With a 1% survival rate from fry to adult, approximately 1500 adult chum would return to the channel.

Proposed Work

Immediately after construction, fry were visible throughout the channel. After high winter flows it is expected that routine monitoring will be conducted on the channel. As well, it is anticipated that in the spring of 2000, a downstream fry trap will be installed to quantify the production of the channel.

Point of Interest

The Tsuk–si–tay side channel construction was a very important project for the Ditidaht people. Not only were people from the band employed, they were also happy to see restoration works performed to help bring back historical fish numbers in their traditional areas. The Ditidaht First Nation selected the name for the side channel, and it's two spurs. In fact Tsuk–si–tay means "the river behind". This makes reference to the fact that there used to be a channel in that vicinity, that was historically significant to the First Nations, and now the river (side channel) has been brought back to them.

The Ditidaht hosted a channel opening ceremony along with a potluck for all the parties involved in bringing about the completion of the side channel. The Ditidaht spokesman, Joe Thorne, had one thing to say, "THANK YOU".

For Further Information

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Figure 1–40. Looking downstream mid–channel.

Figure 1–41. Equipment working on channel excavation and complexing.

Figure 1–42. Example of cut bank during construction.

VERNON CAMP CREEK RESTORATION

Objectives
Work was undertaken at two project sites in Vernon Camp Creek. The objective for the lower project (VC1DJ1) was the addition of large woody debris (LWD) to a straight section of channel to create local scour pools and instream cover for fry. The upper project site (VC2DJ1) attempted to concentrate the flow spreading through an abandoned camp into a series of deeper pools to prevent juvenile stranding.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Northwest Hydraulic Consultants Ltd. (nhc), Alby Systems Ltd. and C.J. Forest Engineering/Canfor

Proponent/Implementing Partners
Partnership of Canadian Forest Products Ltd., 'Namgis First Nation and International Woodworkers of America (IWA).

Watershed/Stream
Nimpkish River/Vernon Camp Creek

Location
Vernon Camp Creek flows northerly to the abandoned Vernon Camp, turning to the southeast to flow into the upper Nimpkish River above the Vernon Reload. The abandoned camp is approximately 30 km southeast of the town of Woss on northern Vancouver Island.

Introduction
Vernon Camp Creek is a very small 2.8 km^2 watershed with a mainstem length of 3.2 km. The project sites are in the lower reaches of the stream where average gradients are 1 to 2%. Most of the basin lies on the Nimpkish River valley flat where it drains a series of wetlands, beaver ponds and swamps. Only a small portion of the basin lies in the steep valley to the north.

Vernon Camp Creek has supported healthy coho, cutthroat trout, rainbow trout and Dolly Varden char populations in the past (nhc and Alby, 1999a).

Assessments and Prescriptions
Seventy–eight percent of the Vernon Camp Creek basin has been harvested since the railroad opened the area to logging in the 1950s. Logging proceeded slowly on the lower slopes of the basin until the 1970s when 40% of the basin was logged. Since the 1970s logging has proceeded much more slowly on the mid–elevation slopes.

The married quarters of Vernon Camp were established in 1955 and abandoned in 1985. A grade shovel built a ringed drainage ditch around the camp to drain the marshy site. This LWD and pool deficient ditch captured the creek, which until that time had no single main channel through the wetlands. Alders and shrubs dominate the riparian vegetation along most of the channel.

Beavers have colonized the ditch since the camp was abandoned. A particularly large dam has raised water levels and flooded the northwest half of the camp. Juvenile coho and trout follow the flow out of the beaver pond into the grassy camp. These fish are stranded and killed when water levels drop in the summer and the camp dries.

Rehabilitation Work
The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby, 1999c.

VC1DJ1 (LWD Addition)
The main habitat objective at this site was to add LWD in the form of LWD spurs, rootwads or lateral LWD jams to encourage local scour producing pools and providing instream cover. As part of the work, a crew:

- constructed 10 lateral LWD jams to produce scour and add cover;
- constructed one LWD spur to produce scour and add cover;
- added 20 rootwad structures at 10 sites to produce scour and add cover;
- added six LWD across the deactivated spur crossing for cover.

VC2DJ1 (Beaver Pond)
The main habitat objective at this site was to excavate a series of deep ponds in the abandoned campsite below the permanent water table with a small connecting channel to ensure access (Fig. 1–43). As part of the work, a crew and equipment:

- excavated four pools with cover for 160 m^2 of off–channel habitat;
- excavated 85 m of connecting channel to ensure access from the ponds to the main channel;
- constructed 150 m of low berm to prevent further flooding of the camp site;
- constructed four LWD steps to control the grade;
- removed the abandoned railway culvert in reach VC2 to prevent the formation of a barrier to migration.

Construction Cost Summary

Crew Labour	$31,299
Consultants	9,997
Heavy Duty Equipment	10,808
Other Costs	7,929
Total Cost	$60,033

Production Estimates

Using a conservative factor of 1.5 fish/m^2 it is estimated that the pools excavated in the campsite will provide rearing for up to 240 fry (1.5 x 160 m^2). However, the density of fry salvaged during construction was closer to 6 fish/m^2 and this would increase the rearing capacity to 960 fry (6 x 160 m^2).

The greatest biological benefit of these projects is the prevention of juvenile stranding in the abandoned campsite. Approximately 10,000 m^2 of camp area is blocked by the offset berm, preventing fry from entering this area and becoming stranded. Using a factor of 1.5 fish/m^2 we anticipate a saving of 15,000 fish yearly in this system; savings could be as high as 60,000 fish using a factor of 6 fish/m^2.

We suggest using a conservative multiplication factor of 0.65 fish/m^2 to calculate the production benefits from scour pools created by mainstem structures. Final pool measurements will be made during monitoring surveys.

For Further Information

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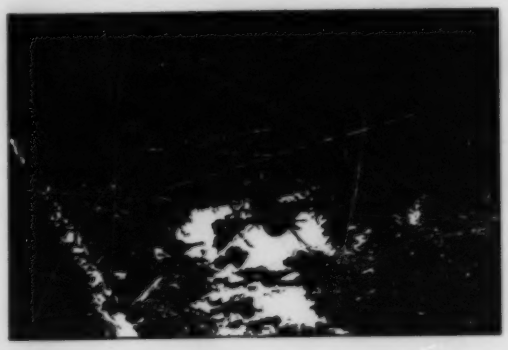

Figure 1–43. Upstream at an excavated pool and the berm in the abandoned camp.

OKTWANCH RIVER SITE 2 GROUNDWATER CHANNEL

Objectives
The objective of the project was to construct a 1.65–km long groundwater–fed channel to provide spawning habitat for sockeye and coho salmon and possibly cutthroat trout and Dolly Varden char. In addition, the channel will provide year–round rearing habitat for juvenile salmonids, particularly coho, as well as resident trout and char.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
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Proponent/Implementing Partners
Western Forest Products Ltd.

Watershed/Stream
Oktwanch River

Location
The Oktwanch River flows in a southeasterly direction into Muchalat Lake approximately 15 km northwest of the town of Gold River. The new channel was constructed in a remnant side channel parallel to the north bank of the Oktwanch River and drains into Muchalat Lake. Take the Nimpkish Road from Gold River and head towards Woss, turn left on to the Muchalat Mainline and cross the Oktwanch River just north of the Muchalat Lake campground to access the project.

Introduction
The Oktwanch River has historically supported runs of sockeye, coho, and chinook salmon. Sockeye abundance has decreased significantly in the past 12 years. Chinook and coho have not been recorded in the Department of Fisheries and Oceans (DFO) escapement records since 1975 and 1977, respectively. During the pre–construction assessments coho were captured indicating that coho still utilize the Oktwanch River. Steelhead, rainbow and cutthroat trout as well as Dolly Varden char also utilize this watershed.

Assessments and Prescriptions
Shawn Hamilton and Associates and Northwest Hydraulic Consultants Ltd. (1997) conducted Overview and Level 1 Fish Habitat Assessments of the Oktwanch River for Canadian Forest Products Ltd., who manage 76% of the watershed.

The results of this assessment showed that increased bank erosion due to past streamside harvesting of trees has resulted in channel widening, in–filling of sections of the channel with sediment, and channel de–watering during summer low flow periods. These channel changes have resulted in a loss of productive rearing habitat, holding areas for returning spawners, and an increased likelihood that fish are lost due to stranding during low flow periods. The reduced surface flow may also delay the upstream migration of spawners in the fall and increase the chance that incubating eggs will de–water during the winter. Eggs may also be lost due to excessive scouring of the channel bed during winter floods.

Channel prescriptions were developed by D. Tripp Biological Consultants Ltd. (1999) in consultation with Fisheries and Oceans Canada (FOC) Habitat and Enhancement Branch for Western Forest Products Ltd., who manage the lands surrounding the project site.

Rehabilitation Work
The project was constructed during March, July, and August 1999. The main channel was constructed in a remnant channel of the Oktwanch River. In addition to the main channel, two side channels, one alcove, and one beaver pond complex were constructed or modified to provide better habitat (Figs. 1–44, 1–45, 1–46). LWD was added to pools and glides and boulders were added to glides and riffles to supply cover.

A berm was constructed along the left bank of the channel to provide 50–year flood protection to the project using gravel from channel excavation.

All disturbed sites were covered with a coastal reclamation seed mixture to minimize erosion and sedimentation to the channel.

Cost Summary

Labour	$ 67,600
Equipment, Rentals, Materials, Misc.	247,400
Total Cost	$315,000

Outputs

1.65 km of channel with an area of 12,760 m^2 was created.

Production Estimates

With a total project area of 12760 m^2 and 120 smolts/ 100 m^2 (Koning and Keeley, 1997) the coho smolt output is estimated at 15,312 smolts. With a marine survival rate of 0.098, the total estimated number of coho adults returning is 1500 fish annually.

The estimated area for sockeye spawning in the main channel is 3126 m^2. Sockeye fry production is estimated at 500 fry/m^2 for a total of 1.6 million fry. Predation by coho on these fry is estimated at 80%, leaving 320,000 fry to enter the lake (R. Doucett, pers. comm., 2000).

Proposed Works

- Construction of LWD bank protection structures in the main channel of the Oktwanch River to help protect the channel.
- Monitoring of the channel for fish use, flow levels, access and channel stability.
- Development of other groundwater channels at Site 2 or other sites in the Oktwanch River Watershed.

For Further Information

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Figure 1–44. Downstream view of the upper channel at station 1+60m showing glide–riffle–pool sequence.

Figure 1–45. Downstream view of lower channel at station 12+25m showing pool with LWD cover.

Figure 1–46. Downstream view of beaver pond.

BIG TREE GROUNDWATER CHANNEL

Objectives
The objectives for Big Tree Creek were to increase off–channel spawning and rearing habitat, a feature found to be lacking in tributaries of the Lower Salmon River (Raven River, 1996). Coho and chum salmon are target species.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
Jesse Brown

Proponent/Implementing Partner
Steelhead Society Habitat Restoration Corporation, MacMillan Bloedel, Forest Renewal BC.

Watershed/Stream
Salmon River/Big Tree Creek

Location
The Salmon River is located on the east coast of Vancouver Island, entering Johnstone Strait at Kelsey Bay, 75 km north of Campbell River. The watershed area is 1200 km^2. Both Elk and Big Tree Creeks are significant salmonid producing tributaries of the Salmon River.

Introduction
Big Tree Creek provides important spawning and rearing habitat for the Salmon River; in which fish production is often limited by lack of off–channel habitat. The Salmon River and Big Tree Creek provide important habitat for chinook, coho, sockeye, chum, pink, steelhead, rainbow, cutthroat, Dolly Varden and kokanee (MELP, 2000).

Assessments and Prescriptions
The site for the development of off–channel habitat is located on a low bench along the right bank of Big Tree Creek, 610 m upstream from the confluence with the Salmon River. The site is fed by groundwater and by two ephemeral streams. Previously there was marginal habitat in the area that is utilized by coho salmon juveniles, however the water was shallow and fish stranding was likely (Fig. 1–47).

Past Rehabilitation Work
The Steelhead Society Habitat Restoration Corp. has conducted restoration activities in the Lower Salmon River that focused on the creation of rearing habitat through the addition of LWD. Concurrent to the 1999/2000 groundwater channel on Big Tree Creek, a riparian treatment rehabilitation project was being conducted 1.4 km to the west.

Rehabilitation Work
A groundwater channel was excavated 610 m west of the confluence with the Salmon River on the mainstem of Big Tree Creek, September 2 to 9, 1999. The channel is 2 to 5 m wide and extends for 400 m for a total habitat area of 800 m^2. The groundwater channel at Big Tree Creek was excavated to a depth 1 m below the groundwater level measured on August 23, 1999 in order to ensure that the channel would not be dewatered (Lister and Finnigan, 1997). Pools were created every 50 m and an overwintering pond was constructed in a swale on the north end of the site. Sixty pieces of LWD were added to the channel/pond complex; LWD were salvaged from the construction of the channel/pond. Material excavated from the channel was placed on the left bank to form a berm to protect the channel from possible flooding from Big Tree Creek (Fig. 1–48).

Cost Summary

Labour	$ 6,288
Equipment and Materials	61,773
Total Cost	$68,061

Outputs

Groundwater Channel	800 m^2
LWD Number	60 pieces

Production Estimates
Based on the WRP Biostandards (Koning and Keeley, 1997) it is expected that the Big Tree groundwater channel would produce 320 coho smolts and 216,000 chum fry, annually.

Proposed Work
All prescribed work was completed during the 1999/2000 field season. It is proposed that all work will be monitored.

For Further Information

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Figure 1–47. Project site prior to construction of the groundwater channel.

Figure 1–48. Project site after the construction of the groundwater channel.

BIG TREE AND SPIRIT CREEKS RIPARIAN RESTORATION

Objectives
The objective was to restore the riparian habitat and function of Spirit and Big Tree Creeks to pre–logging conditions by promoting the establishment and growth of conifers.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
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Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Weyerhaeuser Corporation (MacMillan Bloedel), the Ministry of Environment, Lands, and Parks, and Forest Renewal BC.

Watershed/Stream
Salmon River/Big Tree Creek and Spirit Creek

Location
Spirit Creek, located near the Village of Sayward on the east coast of Vancouver Island, British Columbia, flows predominately east into Big Tree Creek. The project area is 12 km west of Sayward on Hwy. 19 and 2 km west on Big Tree Mainline Road.

Introduction
The riparian vegetation of these creeks was logged in a continuous clearcut between 1946 and 1957. Red alder, with minor components of bigleaf maple (*Acer macrophyllum*) and black cottonwood (Populus *balsamifera ssp. trichoscarpa*), now dominate these riparian areas, providing only low levels of riparian function. Such areas lack the ecological functions provided by large coniferous vegetation.

Assessments and Prescriptions
Silvicultural treatments can promote the restoration of riparian functions provided by large conifers through the creation of the micro–climatic conditions needed for successful conifer regeneration. Gap creation in the red alder stand allows sufficient light for conifer growth (Drever, 2000). Underplanting these gaps with conifer regeneration, associated with brushing of competing shrubs, will allow the establishment and growth of conifers.

Past Rehabilitation Work
Instream work to enhance LWD was completed on Spirit and Big Tree Creeks in 1996 to 1998.

Rehabilitation Work
Restoration work begun on July 15, 1999 and was completed on October 21, 1999. The silvicultural treatment involved creating circular plots of between 18–20 m in diameter (254–314 m^2) by removing 18–21 red alder trees per plot (Figs. 1–49, 1–50). A 5–m buffer of streamside trees was retained to maintain bank stability and provide inputs of nutrients and LWD into Spirit and Big Tree Creeks. All competing shrub species were removed by brushing with a chainsaw immediately following plot creation. The circular plots were planted with large caliper Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and grand fir (*Abies grandis*) large seedlings (10–12 per circular plot) at 2.4 m spacing. Species composition was 70, 20, 10%, respectively. Vexar tubing was installed on red cedar seedlings for browse protection.

Cost Summary

Labour	$24,863
Equipment and Materials	83,615
Total	$108,478

Outputs

Area planted	38 ha

Production Estimates
Not applicable.

Proposed Work
Conifer planting is still needed at the Spirit Creek site. Subsequent brushing treatments are planned in the spring for two years following the initial falling and brushing at both sites. It is likely that additional brushing treatments beyond those planned will be necessary (Von Shilling and Buck, 1999). Survival and brushing surveys are needed to monitor establishment success. Vexar and stake removal will also be necessary.

For Further Information

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Figure 1–49. Pre–treatment canopy at Spirit Creek site.

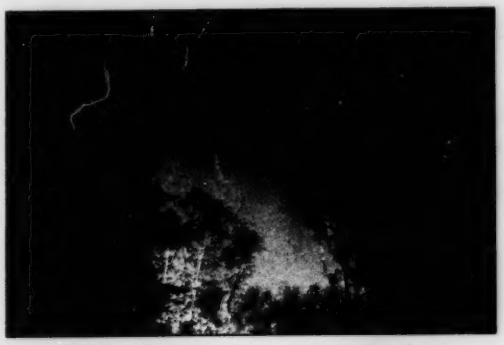

Figure 1–50. Post–treatment canopy at Spirit Creek site.

SAN JUAN RIVER INSTREAM RESTORATION AND SIDE CHANNELS

Objectives
The objective of instream work to date is to restore juvenile rearing and adult holding habitat by complexing existing channels with LWD, riffle/pool sequences, and stabilizing streambanks, all of which provide cover elements and/or promote scour. A side channel was also constructed to try and eliminate trapping of juveniles during low flow periods.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Bud Iverson and Deb Epps

Proponent/Implementing Partners
TFL Forest Ltd.

Partners
Pacheedaht Band, Sooke Renfrew Forestry Society, San Juan Enhancement Society, Cowichan Lake Forest Coop, Renfrew Community Association, IWA.

Watershed/Stream
San Juan River/Tremblay, Mosquito, 4–Mile, Halliday, Harris Creeks and George's Channel

Location
The San Juan River drainage is located on the southwest side of Vancouver Island, approximately 60 km west of Victoria.

Introduction
The San Juan River drainage is one of the larger systems on Vancouver Island. It supports a variety of important fish stocks and wildlife. The San Juan River is known for its high production of salmon for the commercial fishery, and for its sport fishing opportunities particularly for summer steelhead.

For many decades, the San Juan River Watershed has undergone intensive forest harvesting. Earliest logging probably started before the turn of the century and centred initially on the lower delta. By the mid–1990s, large areas of many of its sub–basins had been logged and were in various stages of regeneration.

Assessments and Prescriptions
Instream assessments in the San Juan indicated that the watershed suffers from classic impacts of logging. These range from loss in habitat complexity to widening and infilling of stream channels. These impacts affect all species of salmonids in one way or another throughout their freshwater lifestages.

Instream prescriptions were developed by LGL Limited/ Thomson (1998) for implementation during summer of 1998. Due to unforeseen circumstances no instream projects were accomplished during 1998. Construction was conducted in 1999, using modified LGL Limited/ Thomson (1998) prescriptions, at a number of sites within the watershed. Prescriptions varied from LWD/Boulder complexing to riffle/pool sequencing to side channel excavation.

1999 Construction
The following projects were completed:

Tremblay Creek:
Additional LWD (150 pieces) was placed in the stream following the prescriptions prepared by LGL Limited/ Thomson 1998. A 311 Caterpillar excavator was used to place the clusters into the side channel and associated ponds (Fig. 1–51).

In total, approximately 1250 m^2 of coho rearing area was created (250 m length). Estimated production is 1250 coho smolts (i.e., 1 smolt/m^2) Approximately 350 m^2 of complexing cover was introduced in both years.

Mosquito Creek:
Following the modified plan, the addition of LWD and rock occurred at five sites (Fig. 1–52). The LWD was placed at the assembly area in the fall of 1998 and in August 1999 approximately 150 0.6–m rocks were assembled prior to commencing the instream work. Prior to the complexing at Site 5 a fish salvage crew spent a day electrofishing selected pools (Fig. 1–53).

The carrying capacity of the 250 m of stream will approximate 5000 coho (i.e., 1 smolt/m^2).

Approximately 600 m^2 of complexing was added.

4–Mile Creek:
The side channel was constructed using a Samsung 210 tracked excavator, for a length of 350 m. In addition, a 460 m groundwater channel was constructed, which is connected to the side channel at approximately the mid–way point. Deep pools were constructed in both the main and groundwater channels. Complexing was introduced into all the pools (Fig. 1–54).

Two weirs were constructed; the upper weir restricts low flows to enter the new side channel only. The lower 'V' weir in the new channel only allows for 25% of the high flows to enter the new channel with remainder flowing into 4–Mile Creek (Fig. 1–55).

The carrying capacity of the 4800 m^2 of wetted area at low water levels is sufficient for the rearing of 4800 coho smolts (i.e., 1 smolt/m^2 of surface area). Approximately 1600 m^2 of complexing was added as well as 50 m^2 spawning habitat.

George's Channel:
This channel was initially constructed in 1997, however the difference in bed elevation at the top end of the channel resulted in very minimal flows. In mid–September 1999 three pools were excavated in the upper portion of the channel using a Samsung 210 excavator and a portion of the assembled 70 stumps were placed into the pools with the remaining stumps providing additional complexing to the lower 50 m of channel. During the excavation of the pools additional groundwater was encountered, increasing the water flow in the channel.

The carrying capacity of the approximately 900 m^2 of coho rearing area was further enhanced with an estimated production is 900 coho smolts (i.e., 1 smolt/m^2 of surface area).

Approximately 130 m^2 of complexing was added.

Halliday Creek:
In order to stabilize the riffles, constructed in 1997, it was necessary to add 90 m^3 of 0.4–0.6 m rock to the existing riffles. This larger rock was used mainly for crest rocks and riffle toe rocks. The material in the original riffles was reused to key in the larger rock. Gravel was added to allow spawning in the downstream end of the pool just adjacent to the reconstructed riffles. LWD was placed in the pools generally following the prescriptions prepared by LGL Limited/Thomson (1998) (Fig. 1–56).

Prior to construction a fish salvage crew spent a day electrofishing the pools in Halliday Creek. The results of the electrofishing indicated that in the 250 m^2 of habitat created in 1997, there were 1136 fish removed including 1136 coho and 314 cutthroat trout. The holding capacity should improve slightly with the added 30 m^2 complexing cover. Spawning habitat was increased by 40 m^2.

Harris Creek:
The prescription called for three sites to provide cover and scour by installing LWD structures in mid–channel sites or adjacent to existing vegetated gravel bars. Anchoring rocks were drilled at the assembly area and made into necklaces in readiness for the helicopter to place over the logs. All the materials were air–lifted to sites with a S64 helicopter.

The structures will scour a pool proximal to the rootwad and the LWD and rock will provide cover and some refuge for fish during all flows (Fig. 1–57).

Assessments and Monitoring

Level two assessments were carried out on Lens Creek and Green Heron this fall and winter. Effectiveness monitoring is being conducted by the British Columbia Conservation Foundation, in the winter of 2000, on three instream locations, restored through WRP. The sites being monitored are on Renfrew Creek, Harris Creek and Crompton Slough. The results at this time are not known.

Cost Summary

Labour (est.)	$ 80,000
Materials and Equipment (est.)	90,000
Total	$170,000

2000 Proposed Works

The following table identifies works proposed for 2000:

Renfrew Creek	*Improve habitat and complex.*
Lower Harris Creek	*Improve habitat and complex.*
Crompton Slough	*Complex present habitat.*
Riparian	*Improve riparian habitat.*
Monitoring	*Monitor selected sites developed by WRP.*

Continue with assessments and prescription development.

For Further Information
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Figure 1–51. LWD clusters in Tremblay Creek (downstream view).

Figure 1–52. LWD/Bolder complexing in Mosquito Creek (upstream view).

Figure 1–53. Mosquito Creek electrofishing (upstream view).

Figure 1–54. Pool with LWD complexing in 4–Mile Creek side channel (downstream view).

Figure 1–55. Lower 'V' weir in 4–Mile Creek side channel (upstream view).

Figure 1–56. Crew attaching the LWD to the rock in Halliday Creek (view downstream).

Figure 1–57. Attaching rock to the LWD with rootwad attached in Harris Creek (downstream view).

SARITA RIVER WATERSHED INSTREAM RESTORATION

Objectives
The objectives of this project are to improve and create fish habitat for salmonids by constructing large woody debris (LWD) structures, side channels and riffle pool sequences.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Author
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Proponent/Implementing Partners
Huu-ay-aht First Nation and MacMillan Bloedel.

Watershed/Stream
Sarita River/Sarita and South Sarita Rivers and Sabrina Creek

Location
The Sarita River enters Numukamis Bay in Barkley Sound (on the central west coast of Vancouver Island), approximately 12 km northeast of Bamfield. Its drainage is 189.72 km^2 with the majority of the watershed below 800 m elevation. The basin is comprised of provincial Crown, Indian Reserve and private lands.

Introduction
The Sarita River has historically supported populations of chum, coho, chinook, sockeye and pink salmon, steelhead, rainbow and cutthroat trout and Dolly Varden char. In general, logging has negatively affected stream habitat and riparian areas. Early logging along the mainstem (1950s and 1960s) left little or no riparian buffer along most of the fish-bearing portions of the stream. This resulted in channel widening, channel/bank instability, infilling of pools, reduced surface flow, and loss of LWD throughout the watershed. Some areas in the upper watershed suffered from recent (1995) clear-cut logging to the streambank.

Assessments and Prescriptions
A Level 1 fish habitat assessment for this watershed concluded that chinook, coho and steelhead production was limited by available rearing (for juveniles) and holding (for adults) habitat during low flow conditions, exacerbated by insufficient pool habitat and pool cover. To address this, Level 1 and 2 assessments recommended the maintenance and expansion of deep pool habitat with adequate instream cover and the construction of side channels and of riffle-pool sequences.

Past Rehabilitation Work
Previous restoration work proceeded in 1998. LWD structures were installed at two sites on the Sarita River, at one site on the South Sarita River and at one site at the confluence of the Sarita and the South Sarita Rivers. A 150-m long side channel along the South Sarita River was also built to provide off-channel habitat, especially for coho fry.

Rehabilitation Work
In 1999, the work sites were mainly in two areas: Sabrina Creek, which flows into the South Sarita River, and the mainstem of the Sarita River.

Reach 34 – Sabrina Creek. Four riffle structures were built with a 20:1 downstream face and with a range of rock sizes. Large boulders (>0.6 m diameter) were randomly placed on the surface of the riffle creating chutes and small drops that provide diverse rearing habitat for parr and assist fish passage at low flows. Seven LWD structures, comprised of 2 to 7 logs with rootwads, were built over a distance of 450 m.

Reach 35 – Sabrina Creek. Two logjams were lowered in the upper section of this reach. To provide cover and scour at existing and re-constructed pools, LWD structures were constructed using 3 to 5 logs at 25 specific sites along 1.25 km of Reach 35.

Reach 3 and 4 – Sarita River. A fishway was built for coho fry to access and to exit beaver ponds. The fishway consisted of 9 steps made from 2 to 5 cedar logs embedded into the streambed and banks, fastened together with rebar and covered with thick plastic. Each step had a drop of 10-12 cm (Fig. 1-58).

To provide cover and scour at existing and re-constructed pools, LWD structures were built at 9 sites with 1 to 5 logs with rootwads. The LWD structure downstream of Blenheim Bridge was reconfigured and 4 logs added (Fig. 1-59).

Reach 20 – South Sarita River. To provide cover and scour at existing pools, 2 to 5 logs with rootwads were anchored at two sites.

A 'band–aid' approach was taken to place riprap along a 60–m long section of riverbank of Reach 20, where the South Sarita River literally flows on the main Bamfield road during high flows. Prescriptions for this 300–m long eroding bend and the placement of lateral spurs will be undertaken in 2000 to prevent the South Sarita River from spilling onto the main road.

Cost Summary

Wages and Consultants	$ 73,820
Equipment Purchase and Rental	22,377
Machinery including Air–Crane	113,903
Administration	17,900
Total Cost	$228,000

Outputs

600 m of instream work on mainstem Sarita River
60 m of streambank work on South Sarita River
1.7 km instream work in Sabrina Creek

Production Estimates

Numerous fry were observed in all LWD structures during swim counts carried out during the autumn of both years. No fry were observed in the side channel in 1998. However, coho fry were observed to occupy the side channel during all seasons in 1999. No quantitative estimates were obtained although minnow traps were placed on two occasions.

No fry were observed in Reach 35 of Sabrina Creek prior to and during construction of the LWD structures. To assess the effectiveness of the structures, minnow traps were placed for a minimum of two hours on November 10 at 12 sites and on November 17 at four sites. Between 0 and 3 steelhead were taken at each site for a total of 11 fry, 6 cm mean length on November 10 and four fry, 8 cm mean length on November 17.

Proposed Work

The Sarita Watershed Restoration Project will continue for many years. In 2000, proposed work includes: LWD structures in Frederick, Hunter and Sabrina (Reach 37) Creeks; 500–m long side channel with LWD structures in the Sarita River (Reach 2); LWD structures on the South Sarita River (Reach 20). The two logjams on Reach 35 of Sabrina Creek will again be lowered in 2000.

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Figure 1–58. Fishway as it first fills with water from the beaver ponds.

Figure 1–59. LWD structure that provides scour and cover in a deep pool on Sarita River.

LOWER TAYLOR RIVER GROUNDWATER CHANNEL CONSTRUCTION

Objectives

The primary objectives of this project are to increase the productivity capacity of the Taylor River Basin by:

- rehabilitating the upper reach of Tributary 5000.101.1 and Pond #2, to improve flow and fish access to Pond #2;
- developing a groundwater channel between Pond #2 and Tributary 5000.105 to increase the spawning and rearing capacity of the area; and
- connecting isolated ponds to the new channel (5000.101.1.2).

FRBC Region/MELP Region/MOF Region

Pacific/Vancouver Island/Vancouver

Authors

Michael C. Wright and Teresa L. Wright, M.C. Wright and Associates

Proponent/Implementing Partners

A partnership of Weyerhaeuser, M.C. Wright and Associates, Fisheries Renewal BC, Fisheries and Oceans Canada–HRSEP, Hupacasath First Nation and Summit Power Management Corporation.

Watershed/Stream

Taylor River

Location

The Taylor River Watershed is the headwater of the Sproat Lake Watershed. The construction site is located approximately 35 km west of Port Alberni and can be accessed by driving 0.5 km along the Weyerhaeuser South Taylor main logging road.

Introduction

The streams of the Taylor Basin have historically supported spawning and rearing areas for sockeye, coho, chinook, steelhead and cutthroat trout. Utilization by chinook was confirmed by the Fisheries and Oceans Canada in 1997. Although minor logging activities occurred just above the outlet of Sproat Lake between 1905 and 1911, the Taylor Basin has only really been subjected to logging activities since the 1960s, with the most extensive logging occurring during the 1970s (Horel, 1996). The logging activities on the low–gradient alluvial reaches of the lower Taylor River have had the greatest impacts on the mainstem and off–channel fish habitat. In addition to the impacts of logging the Taylor Basin has suffered negative impacts from the construction of Highway #4 and recreational activities throughout the lower 7.5 km.

Assessments and Prescriptions

During 1998 and 1999 the Taylor River has been the subject of an extensive Differential GPS mapping project (funded by FRBC in 1998 and HRSEP in 1999), which created an overview map clearly showing location, and types of fish habitat. The mapping exercise also identified habitat impacted by human encroachment and opportunities for restoration and/or creation of habitat. Results from the mapping of the Taylor River Watershed have shown that the impacts to and loss of off–channel habitat has had the greatest impact on coho production in the system. To address the issue of impacted and lost off–channel habitat the groundwater channel was constructed to provide stable off–channel spawning and rearing habitat (Fig. 1–60).

After consultation with representatives of Fisheries and Oceans Canada, Ministry of Environment, Land and Parks, Nuu–chah–nulth Tribal Council and Hupacasath First Nation a prescription was developed to construct the groundwater channel and rehabilitate 310 m of Tributary 5000.101.1 (Pond #2 outlet channel) thereby increasing the productive capacity of the Taylor River. The prescription was developed by M.C. Wright and Associates during the summer of 1999.

Rehabilitation Work

The construction of the groundwater channel occurred between August 30 and September 20 and September 29–30, 1999. As–built surveys (DGPS and Rod and Level) were completed on October 15, 1999. Central Island Excavating did the excavation of the channel.

The groundwater channel was originally designed for a mainstem length of 625 m but was shortened to 525 m due to limited groundwater supplies above this point. Instead, an additional 209 m of side channel was created on the left bank. During excavation an alcove–type pond was created to provide spawning and rearing habitat. A borrow pit and isolated pond were connected to the mainstem providing additional rearing habitat. With the exception of 42 truckloads of gravel all of the excavated

material was side cast. The channel has a mean width of 4.15 m (range: 2.6 m to 5.4 m). Riffles, pools and glides had mean depths of 0.22 m (range: 0.14 to 0.40 m), 0.98 m (range: 0.76 to 1.19 m) and 0.53 m. (range: 0.17 to 0.69 m), respectively.

Large woody debris was collected during the clear and grub phase of the project and added complexity to the channel through the construction of nine artificial cutbanks which provided approximately 108 m^2 of cover (Fig. 1–60). Several configurations of placement were used; cross logs (singular and paired), stumps buried into banks and small debris jams, which provide complex refuge areas. LWD (stems and/or stems with rootmass) were keyed into the banks, some of the wood was placed on the bank and projected into the channel or cabled into place. Approximately 180 pieces of LWD, 15 stumps and four rootwads were used for complexing the channel. Once the channel was complexed the remaining wood debris from the clear and grub phase of the project was placed on the stream banks and other disturbed areas for erosion control. Although this approach is not aesthetically pleasing in the short term, the long–term benefits are high.

Benefits include: reducing velocity of runoff, trapping sediment on the slope, and the wood provides habitat for small animals and birds. As the disturbed areas revegetate the woody debris becomes obscured, blending in with the surrounding environment.

Cost Summary

Labour	$19,500
Machinery and Materials	26,626
Total Cost	$46,126

Outputs

0.74 km of off–channel stream habitat was created, 0.31 km of off–channel habitat and 1.12 ha of pond was rehabilitated, and 0.10 ha of off–channel pond habitat was connected.

Production Estimates

The groundwater channel project provides an additional 1500 m^2 of rearing habitat, year–round access to 1.12 ha of pond habitat, 3071 m^2 of new stable spawning and rearing habitat and access to 0.10 ha of off–channel pond habitat. Based on the bio–standards (Koning and Keeley, 1997) the estimated capacity of the channel (and rehabilitated areas) with a density of 1.01 coho fry/m^2 would be 16,938 coho fry. With a survival rate of 0.68 a total of 11,518 coho smolts will be produced. In addition based on recommended area per spawning pair of coho and sockeye (11.7/m^2 and 6.7/m^2, respectively) the groundwater channel could support 291 and 507 spawning pairs of coho and sockeye, respectively.

Proposed Work

The channel should be monitored for bank stability and success of revegetation, utilization by juvenile and adult salmonids, and LWD structures should be maintained.

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Figure 1–60. The groundwater channel prior to construction at 0+200 m.

Figure 1–61. A partially constructed cutbank on the groundwater channel.

LOWER TAYLOR RIVER—RELIC CHANNEL EXTENSION

Objectives
The primary objective of this project is to increase the rearing and spawning capacity of the Relic Channel by increasing the length of the channel by 300 metres.

FRBC Region/MELP Region/MOF Region
Pacific/Vancouver Island/Vancouver

Authors
Michael C. Wright and Teresa L. Wright, M.C. Wright and Associates

Proponent/Implementing Partners
A partnership of Weyerhaeuser, M.C. Wright and Associates, Fisheries Renewal BC, Fisheries and Oceans Canada–HRSEP, Hupacasath First Nation and Summit Power Management Corporation.

Watershed/Stream
Taylor River

Location
The Taylor River is the headwater of the Sproat Lake Watershed. The construction site is located approximately 45 km west of Port Alberni and can be accessed from Highway #4.

Introduction
The streams of the Taylor River Watershed have historically supported spawning and rearing areas for sockeye, coho, chinook, steelhead and cutthroat trout. Fisheries and Oceans Canada confirmed utilization by chinook in 1997. Although minor logging activities occurred just above the outlet of Sproat Lake between 1905 and 1911, the Taylor basin has only really been subjected to logging activities since the 1960s, with the most extensive logging occurring during the 1970s (Horel, 1996). The logging activities on the low–gradient alluvial reaches of the lower Taylor River have had the greatest effects on the mainstem and off–channel fish habitat. The construction of Highway #4 and recreational activities throughout the lower 7.5 km have also negatively affected the Taylor River.

Assessments and Prescriptions
During 1998 and 1999 the Taylor River has been the subject of an extensive differential GPS mapping project (funded by FRBC in 1998 and HRSEP in 1999), which created an overview map clearly showing locations and types of fish habitat. The mapping exercise also identified habitat impacted by human encroachment and opportunities for restoration and/or creation of habitat. Mapping of the Taylor River watershed showed loss of off–channel habitat and effects upon remaining off–channel habitat has had the greatest impact on coho production in the system. The Relic Channel was constructed in 1998 to provide stable off–channel spawning and rearing habitat and to address the issue of impacted and lost off–channel habitat. Based on the success of the original Relic Channel, the Relic Channel Extension was selected as a good restoration opportunity (Fig. 1–62).

After consultation with representatives of the Fisheries and Oceans Canada, Ministry of Environment, Land and Parks, Nuu–chah–nulth Tribal Council and Hupacasath First Nation a prescription was developed to further increase the productive capacity of this off–channel habitat. M.C. Wright and Associates developed the prescription during the summer of 1999.

Rehabilitation Work
The construction of the Relic Channel Extension occurred between August 17 and August 30, 1999. As–built surveys (DGPS and Rod and Level) were completed on September 3, 1999. Central Island Excavating excavated the channel.

Construction commenced on August 17 with preparation of the work site (clearing and grubbing, a cofferdam was constructed to contain silt and barrier nets were installed to prevent fry migration into the Relic Channel Extension). The Relic Channel Extension was cut in two stages, the first cut was down to just above the water table while the second cut lowered the channel bed to final grade, between 0.5 and 1.0 m below the level of groundwater during low summer flows. All of the excavated material was sidecast in order to keep construction costs from being prohibitive. The channel has a mean width of 4.0 m (range: 2.04 to 5.9 m). Riffles, pools and glides had mean depths of 0.21 m (range: 0.11 to 0.36 m), 0.95 m (range: 0.81 to 1.01 m) and 0.47 m (range: 0.24 to 0.66 m), respectively.

Complexing of the channel was completed using large woody debris collected during the clear and grub stage of the project. Several configurations of placement were used; cross logs (singular and paired), stumps buried into banks and small debris jams, which provide complex refuge areas. LWD (stems and/or stems with rootwad) and stumps were either buried or keyed into the banks, some of the wood was placed on the bank and projected into the channel or cabled into place. Approximately 83 pieces of LWD and 12 stumps were used for complexing the channel. Once the channel was complexed the remaining wood debris from the clear and grub phase of the project was placed on the streambanks and other disturbed areas for erosion control. Although this approach is not aesthetically pleasing in the short term, the long–term benefits are high (Fig. 1–63).

Benefits include reducing velocity of runoff, trapping sediment on the slope and, the wood provides habitat for small animals and birds. As the disturbed areas revegetate the woody debris becomes obscured, blending in with the surrounding environment.

Cost Summary

Labour	$13,645
Machinery and Materials	14,205
Total Cost	$27,850

Outputs

0.30 km of off–channel stream habitat was created.

Production Estimates

The Relic Channel Extension will provide an additional 1200 m^2 of rearing and spawning habitat. Based on the bio–standards set out in Koning and Keeley (1997) the estimated capacity of the channel with a density of 1.01 coho fry/m^2 would be 1212 coho fry. With a survival rate of 0.68, a total of 812 coho smolts will be produced. In addition based on recommended area per spawning pair of coho (11.7/m^2) the Relic Channel Extension will support 102 spawning pairs of coho.

Proposed Work

The Relic Channel Extension requires that we monitor bank stability and success of re–vegetation, monitor and maintain the LWD structures, and monitor the utilization of habitat by juvenile and adult salmonids.

For Further Information

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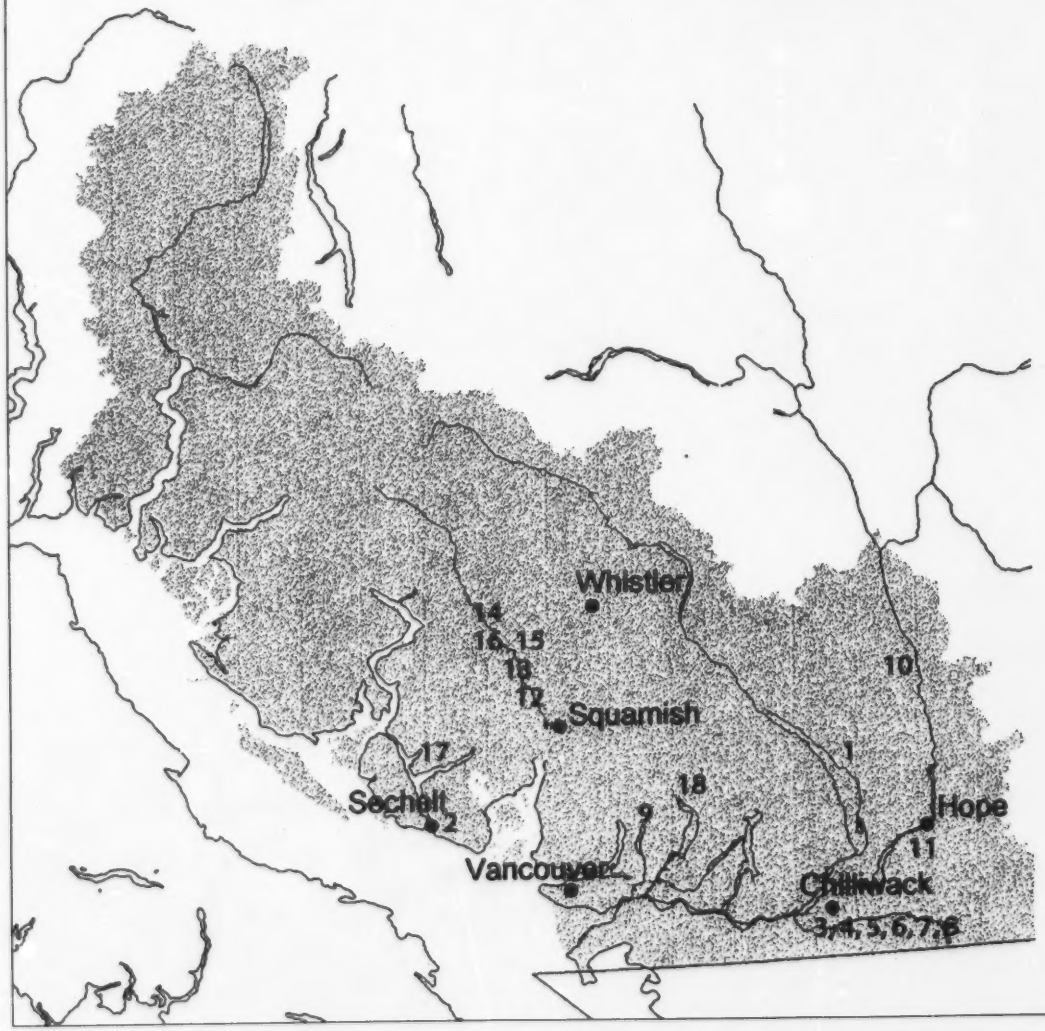
Figure 1–62. Confluence of the Relic Channel and Relic Channel Extension at the start of construction.

Figure 1–63. Confluence of the Relic Channel and Relic Channel Extension post–construction.

Lower Mainland Region

Region 2. Lower Mainland



WRP Projects

1	Big Silver Creek
2	Chapman Creek
3, 4	Chilliwack River
5	Deer Creek
6	Millennium Ponds
7, 8	Slesse Creek
9	Forestry Creek
10	Strutzel Pond
11	Silverhope Creek
12	Ashlu Creek
13	High Falls Creek
14	Shop Creek
15	28.5 Mile Creek
16	36 Mile Creek
17	Tzoonie River
18	Elizabeth Joe

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 2, Lower Mainland.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Lower Mainland	Big Silver Creek	Big Silver Creek Integrated Watershed Monitoring	10	5492054	584681	110–599000	00000HARR
2		Chapman Creek	Chapman Creek Off-channel Habitat	10	5476570	447557	900–120400	00000JERV
3		Chilliwack River	Chilliwack River Instream Restoration	10	5441863	565776	100–065700–09700	00000CHWK
4		Chilliwack River	Chilliwack River LWD Placements	10	5441863	565776	100–065700–09700	00000CHWK
5		Chilliwack River	Deer Creek Groundwater Pond	10	5436479	582545	100–065700–09700–22400	00000CHWK
6		Chilliwack River	Millennium Ponds	10	5439000	604000		00000CHWK
7		Chilliwack River	Slesse Creek R1 Groundwater Pond	10	5436974	594273	100–065700–09700–3800	00000CHWK
8		Chilliwack River	Slesse Creek R4 Road Deactivation and Pond Development	10	5436974	594273	100–065700–09700–3800	00000CHWK
9		Indian River	Forestry Creek Groundwater Channel and Ponds	10	5485612	507155	900–05600–27500	00000SQAM
10		Nahatlatch River	Strutzel Pond Complex	10	5537231	606735	100–170100	00000FRCN
11		Silverhope Creek	Silverhope Creek Riparian Treatments	10	5469792	611589	100–112900	00000FRCN
12		Squamish River	Ashlu Creek Channel Complexing and Bar Revegetation	10	5527287	478757	900–097600–38300	00000SQAM
13		Squamish River	High Falls Creek Groundwater Channel	10	5531631	477881	900–097600–44000	00000SQAM
14		Squamish River	Shop Creek Groundwater Channel	10	5550800	472200	900–097600–70400–03753	00000SQAM
15		Squamish River	28.5 Mile Creek Overflow Spillway Modification	10	5540029	475754	900–097600–54800	00000SQAM
16		Squamish River	36 Mile Creek Pond	10	5548995	473750	900–097600–66800	00000SQAM
17		Tzoonie River	Tzoonie River Riparian Restoration	10	5515642	448196	900–195000	00000JERV
18		Upper Pitt River	Elizabeth Joe Groundwater Channel	10	5498000	524000		00000LFRA

BIG SILVER CREEK INTEGRATED WATERSHED MONITORING PROJECT

Objectives
The objectives of the Big Silver Creek pilot project are to test procedures and facilitate integrated monitoring of hillslope and stream components on a watershed level.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Pat Slaney and Daiva Zaldokas

Proponent/Implementing Partners
International Forest Products Ltd. (Interfor), Hope Logging/Ministry of Environment, Lands and Parks, B.C. Conservation Foundation, Fisheries and Oceans Canada and Western Forest Products Ltd. Partnership with Ministry of Forests is proposed for hillslope evaluations.

Watershed/Stream
Big Silver Creek/Hornet Creek and Clear Creek

Location
Big Silver Creek is located 35 km north of the town of Harrison Hot Springs; 2 hours drive from Vancouver. Vehicle access is via a main gravel road, 45 minutes from Harrison Hot Springs. Access to the mainstem is possible from a mainline logging road that parallels the river from the lake to the logging camp at river km 15.

Introduction
The river originates from the Lillooet Range of the Coast Mountains, east of Harrison Lake, and flows predominantly west into the lake, which has an area of approximately 28,243 ha. River flows are maintained through the summer via snowfields in the headwaters. Total length of the mainstem from headwaters to mouth is approximately 40 km (Fig. 2–1). The lower 15 km of the mainstem channel is stable and contains only a single major side channel 2 km up from the mouth.

The predominant human activity in the area for the past 40 years has been logging. Sparse old growth exists on the lower slopes of the watershed but secondary growth is well established and the slopes and roads on the mainstem are relatively stable. Tributary sub–basins have had varying amounts of logging. Of the larger ones, Clear (7 km) is most stable (Fig. 2–2) and Hornet Creek (3 km) is least stable (Fig. 2–3), as related to percentage logged and soils.

The lower river to km 6 (falls) supports populations of sockeye, chinook, coho and chum salmon; winter steelhead, cutthroat and lacustrine rainbow trout; Dolly Varden and mountain whitefish (*Prosopium williamsoni*). Resident rainbow trout and possibly a few steelhead utilize boulders and canyon habitat from km 6 to km 15. Preliminary assessments, including extensive underwater counts, indicates very limited off–channel habitats, nutrient limitations and a lack of large woody debris.

Assessments and Prescriptions
Interfor completed an operational inventory survey in 1998/99. Western Forest Products, the other licensee has completed (1999/2000) an overview assessment of approximately 6,500 ha and detailed assessments and road deactivation prescriptions on 7 km of road in the Hornet Creek sub–basin.

Past Rehabilitation Work
A Fisheries Research and Development fertilization experiment (Bacci design) was conducted in Big Silver Creek Watershed from 1991 to 1997. Primary objectives in the first three years were to obtain baseline (pre–fertilization) and control–reach data on three reaches of the river below a large falls at km 15, and on the two main tributaries, Hornet and Clear Creeks. The Big Silver mainstem was fertilized during the summers of 1994–97. Liquid ammonium polyphosphate fertilizer flow was proportionally metred into the treatment reaches using a variety of injection systems to maintain target concentrations of 5 $\mu g \cdot L^{-1}$ P, between June and October. The physical, chemical and biological components of the system were monitored throughout the project. The addition of phosphorus–based fertilizer stimulated growth at all trophic levels monitored, as detailed in Wilson *et al.*, 1999. Fertilization has continued with the addition of nitrate nitrogen in 1999, but was discontinued in 2000.

Rehabilitation Work
In 1999/2000 Western Forest Products completed 4 km of road deactivation work in the Hornet Creek sub–basin. This work was halted due to inclement weather.

WRP Monitoring Work

MELP, Technical Coordination Section initiated monitoring of suspended sediments and turbidity of the mainstem Big Silver, Clear Creek and Hornet Creek in mid–October, 1999. Clear Creek is being used as a reference watershed because of limited logging activities to date (old fire burn). Water levels are also being monitored at the two main tributaries for establishing stage–discharge relationships. Fish enumeration in the mainstem and these tributaries are being continued. Effectiveness evaluations will continue in 2000/01.

Cost Summary *(Estimated)*

Labour	$6,500
Equipment and Materials	4,900
Total Cost	$11,400

Proposed Work (2000/2001)

Plans are for Interfor to complete a Level 1 FHAP on the lower 5 km of stream this winter, assessing off–channel rehabilitation opportunities and LWD replacement sites. An overview riparian assessment will also be conducted on this section of river. A partnership will be formed with Interfor, Fisheries and Oceans Canada (FOC) and MELP to design and construct off–channel spawning and rearing habitat. FOC will provide in–kind contribution to the project by supplying engineering, biological support and supervision. LWD structures will be designed via MELP, or a consultant, and materials supplied and constructed by Interfor's forest worker crew. Western Forest Products is planning to complete the remainder of the road deactivation work (3 km) in the Hornet Creek sub–basin and monitor previous hillslope works.

For Further Information

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Figure 2–1. Downstream view of the middle reach of Big Silver Creek.

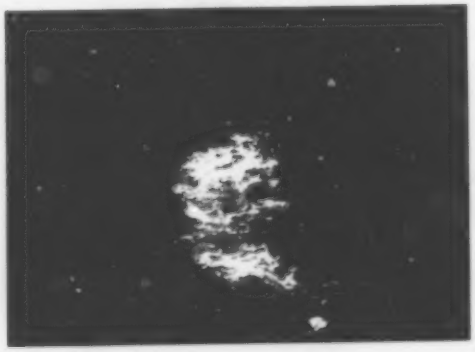

Figure 2–2. Upstream view of Clear Creek from the mainline bridge.

Figure 2–3. Upstream view of Hornet Creek from the mainline bridge.

CHAPMAN CREEK OFF–CHANNEL HABITAT

Objectives
The objective of this project was to increase stable off–channel habitat for rearing and spawning salmonids, particularly coho.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Author
Tanis Douglas

Proponent/Implementing Partners
Ministry of Environment, Lands and Parks, Fisheries and Oceans Canada, and the Steelhead Society Habitat Restoration Corporation.

Watershed/Stream
Chapman Creek

Location
Chapman Creek flows into the ocean just south of Sechelt on the lower Sunshine Coast. Access to the creek is either directly from Highway 101, or from the Chapman Creek Hatchery.

Introduction
Chapman Creek is the primary domestic water supply for the District of Sechelt and surrounding areas. The creek is 27 km long and has a drainage area of 7,315 ha (EVS, 1999). Chapman Creek has been extensively logged, resulting in numerous landslides and channel changes. Anadromous and headwater sections are divided by an impassable falls approximately 6 km from the estuary, and steelhead, coho, pink and chum salmon use the lower reach.

Assessments and Prescriptions
Valuable fish habitat was lost when part of the lower floodplain was dyked in 1955, to protect log booms. Chapman Creek lacks significant refuge habitat, and summer low flows are a problem because of domestic water extraction. Assessments of existing (constructed) off–channel habitat show that the densities of overwintering coho fry are extremely high, probably due to the limited supply of stable off–channel habitat.

Past Rehabilitation Work
Three "Newbury" riffles were completed in 1993, and these riffles have effectively trapped spawning gravels in the lower reach. In 1995, a small backwater channel complex was constructed in the lower floodplain, and this has been used extensively by coho juveniles. There has been extensive road deactivation and bioengineering in the upper watershed.

Rehabilitation Work
A 450–m long spawning and rearing channel was constructed about 2 km upstream from the estuary, on the east side of Chapman Creek (Figs. 2–4 and 2–5). The lower–most section of the construction site previously consisted of two small, abandoned beaver ponds, the lower of which was used by coho juveniles and remained wetted for most of the year.

The new channel is mostly supplied by groundwater, but a surface water intake was also constructed to complement the groundwater flow, as necessary. This 12–inch diameter intake pipe can be turned off for most times of the year, though the water it provides was a great attractant to coho spawners that used the site shortly after construction. This surface water option will be used mainly during the lower flow times of year, except during critical low flow periods when domestic water use is depleting Chapman Creek. During these times, deep ponds will serve as refugia.

A total of five large ponds were created, connected by short riffles of 4–10% slopes (Fig. 2–6). The spawning that occurred on these riffles will be sufficient to seed the site. The large woody debris that was uncovered during construction was used to complex these ponds, and the larger boulders were used to line the banks. The banks and berm were grass seeded, and will be planted with conifers in the spring of 2000.

Cost Summary

Labour	$10,500
Expenses	2,432
Machinery and Materials	24,257
Total Cost	$37,189

Outputs
0.45 km of off–channel habitat was created. This is equivalent to approximately 5500 m^2 of pond habitat separated by short riffle sections.

Production Estimates

Based on the biostandard of 0.67 coho smolts/m^2 (Koning and Keeley, 1997), we might expect 3,685 smolts to emerge in spring of 2001. Earlier data collected from a partially constructed groundwater channel downstream in Chapman Creek suggest smolt production can be up to 2.0 smolts/m^2 (D. Bates, pers. comm.). This channel will also provide habitat for small numbers of cutthroat and steelhead juveniles.

Proposed Work

Conifer trees will be planted on the banks of the new habitat in spring 2000. In summer 2000, additional spawning gravel will be added to the riffles, and the berm at the intake site will be reinforced.

A beaver has built a sturdy dam at the lower–most riffle, and a "beaver screen" was installed to allow for spawner and smolt migration.

For Further Information

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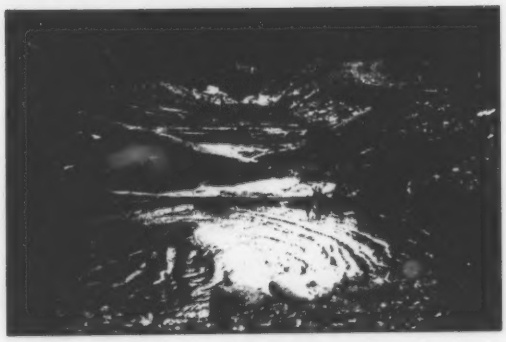

Figure 2–4. Chapman Creek off–channel habitat, downstream view.

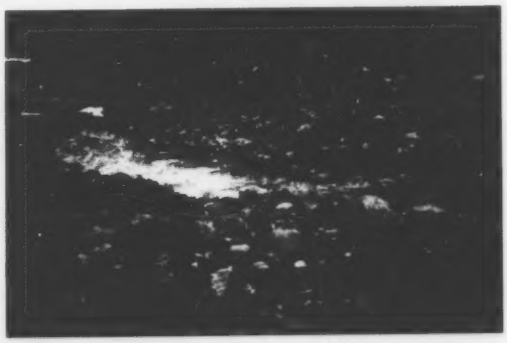

Figure 2–5. Chapman Creek off–channel habitat, riffle.

Figure 2–6. Chapman Creek off–channel habitat, lower–most pond.

CHILLIWACK WATERSHED DEMONSTRATION PROJECTS
CHILLIWACK RIVER INSTREAM RESTORATION

Objectives
The objective of this project is to restore large woody debris (LWD) fish habitat structures throughout various reaches of the upper Chilliwack River.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Author
Bruce Usher

Proponent/Implementing Partners
Tamihi Logging Co. Ltd., Ministry of Environment Lands and Parks, Forest Renewal BC Watershed Restoration Program, Fisheries Renewal BC through the Fraser Valley Regional Watersheds Coalition, British Columbia Conservation Foundation.

Watershed/Stream
Chilliwack River/Chilliwack River

Location
Chilliwack River LWD sites are located 10 km from the Vedder Bridge crossing on the Chilliwack River Road, beginning at Slesse Park hamlet and extending for 2 km upstream.

Introduction
The Chilliwack River Watershed is located in a dry maritime Coastal Western Hemlock (CWHdm) ecosystem. Extensive logging has taken place since the early twentieth century. Most of the riparian areas have been logged, with the majority of the regrowth ranging in age from 30 to 80 years, thereby creating a maximum large wood deficit throughout the entire length of the channel. Further losses of LWD along the mainstem channel have incurred during past flood control measures.

Assessments and Prescriptions
Thirteen sub-basins of the Chilliwack Watershed were assessed for fish habitat quality and quantity by Whelan *et al.*, 1995. Sub-samples of 31 reaches in these tributary streams revealed that 25 were rated poor for LWD per channel width, five rated fair and one rated good. CEJ Mussell Enterprises INC did preliminary site surveys. Stephane D'Aoust of Pottinger Gaherty Environmental Consultants Ltd. provided engineered drawings and prescriptions for the sites. Engineering for the Ford Mt. site and all beaver structures were provided by Rheal Finnigan, B.C. Conservation Foundation for MELP.

Rehabilitation Work
A total of 48 structures were completed within the main channel and off-channel sites of the Chilliwack River. Applications for Section 9.1 were submitted to MELP Water Management and were closely reviewed by the Fraser Cheam Regional District (FCRD) and MELP Water Management engineers to ensure minimal risk of damage or flooding from the structures. A series of engineered drawings by Stephane D'Aoust of Pottinger Gaherty Environmental Consultants Ltd. were developed and submitted as requested by the FCRD. Approval was given for the works to proceed in the reaches of the stream above Slesse Park Hamlet. The type of structure placed was matched to the hydraulic type, i.e., pool, alcove or bank protection on the outside of a curve, Fig. 2-7 gives an example of a structure placed in a pool. Fig. 2-8 shows a debris capture structure designed to protect banks and provide fish habitat. Fig. 2-9 shows a typical beaver baffle structure designed to thwart beaver activity in controlled flow channels (R. Finnigan design). Logs and boulders were placed by a 3-man First Nation's crew and anchored using standard cabling techniques. As-built reports were generated for most structures.

Most structures were placed through out the Allison Canyon and Anderson Creek reach of the mainstem Chilliwack River. Other major works were constructed near the mouth of Foley Creek, Chilliwack River at Thurston Meadows Forest Service Campsite and downstream of Nesakwatch Creek. Additional beaver baffle structures were constructed in Borden Creek Channel, Centennial/Bulbeard Channel and Millennium Channel. Two large wood debris catchers were constructed at Ford Mt. detention camp.

Cost Summary
Tamihi Logging Sidechannel above Anderson Pond (WRP funds)

Labour	$ 4,280
Equipment and Materials	11,824
Survey	1,526
Total Cost	$17,630

Design costs and project review (Pottinger Gaherty Environmental Consultants) for this site are estimated to be approximately $4,532. An additional $2,951 was spent on design works for the remaining sites at Allison Sidechannel, Center Creek pool, Thurston campsite, and Anderson Pond outlet. These costs were borne by Fisheries Renewal BC.

Cost Summary Partnership Projects

Fisheries Renewal Costs	
Project Cost	$29,246
Project Management	2,009
Total Cost	$31,255

Cattermole Logging Costs
(Beaver Baffles—various sites and Debris Catchers at Ford Mt. Camp)

Labour	$ 9,000
Materials	8,700
Equipment	4,500
Total Cost	$22,200

Tamihi Logging provided approximately $8,000 (FRBC) in-kind funding to support projects at the other locations.

MELP (through FRBC) provided $4,000 for a Spyder Hoe and $800 for engineering supervision at the Ford Mt. Camp site.

An additional in-kind contribution of labour (clearing and site preparation) was made by Ford Mountain Correctional Camp.

Outputs
2 km of stream was restored and seven beaver baffle structures were placed. Two debris catcher structures were completed at Ford Mt. Camp. Thirty-nine LWD structures were placed at various locations throughout the Chilliwack River above Slesse Park Hamlet.

Production Estimates
Biostandards for LWD placement are not well formulated. For 39 structures the following estimates of fish production are:

Estimated area improved: 12025 m^2
Estimated return of coho: 694 adults
Estimated return of steelhead: 87 adults
(Koning and Keeley, 1997).

Proposed Work
Additional works are planned for lower Slesse Creek at R-1 to protect a clay bank.

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Figure 2-7. Allison LWD lower pool after 1 hour.

Figure 2-8. A debris catcher at Fort Mt. Camp.

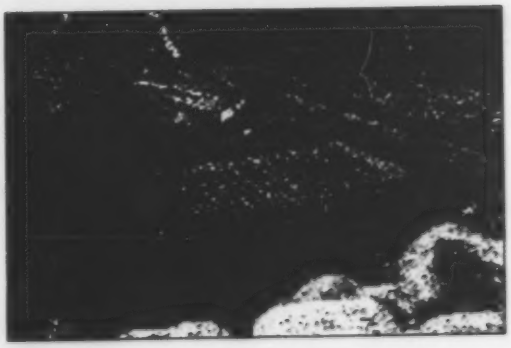

Figure 2-9. Beaver baffle.

CHILLIWACK RIVER LWD PLACEMENTS

Objectives
The objectives of this project were to construct large wood–boulder complexes to induce scour in the channel bed, to form holding pools and to provide instream cover for adult and juvenile salmonids.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Author
Jesse Brown

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation (SSHRC), Ministry of Environment, Lands and Parks, and Forest Renewal BC.

Watershed/Stream
Chilliwack River

Location
The Chilliwack River LWD sites are located 32 km south of the Vedder Bridge Crossing on the Chilliwack River Road, beginning at the Centre Creek Youth Corrections facility and extending for 2 km upstream.

Introduction
The Chilliwack River drainage is located in the lower mainland (MELP Region 2) approximately 100 km east of Vancouver, BC. Logging has occurred extensively throughout the area since the early 1920s. The Chilliwack River also supports commercially and recreationally important populations of salmon, trout and char. Annual steelhead angler–effort in the Chilliwack River frequently exceeds 50,000 angler–days (M.A. Whelan and Associates Ltd. and the Steelhead Society of BC, 1995).

Assessments and Prescriptions
The WRP has designated the Chilliwack River drainage a high priority watershed due to the intensive forest harvesting and important fisheries within the watershed. The major forestry–related impacts to the Chilliwack River are the reduction in habitat complexity, increase in bank instability, widening of the channel, loss of riparian function and increased sediment loads. LWD/boulder complexes designed for the side channels of the Chilliwack River will increase available spawning and rearing habitat for salmonids improving survival during significant flood events.

Past Rehabilitation Work
The Chilliwack River Watershed has been the site of numerous restoration projects since 1993. The restoration area specifically focused on in this project has received no previous restoration work.

Rehabilitation Work
The Steelhead Society Habitat Restoration Corporation initiated restoration on the Chilliwack River during the 1999 fisheries window. Due to the difficulty in obtaining adequate LWD, not all instream works were completed before the end of the fisheries window, however, LWD was stock piled to expedite next year's work. The wood–boulder complexes were constructed at one of the four proposed sites in side channels of the Chilliwack River. Sites that could not be completed within the fisheries window are to be completed in the 2000/01 season. All sites were located near the confluence of Centre Creek and the Chilliwack River, approximately 32 km up the Chilliwack River Road (Figs. 2–10 and 2–11).

Cost Summary

Labour	$10,825
Equipment and Materials	6,090
Total Cost	$16,915

Outputs

Habitat Complexing	0.1 km

Production Estimates
Production estimates are uncertain; some structures require reworking.

Proposed Work
The three LWD/boulder complexes will be completed in the 2000/01 field season.

For Further Information

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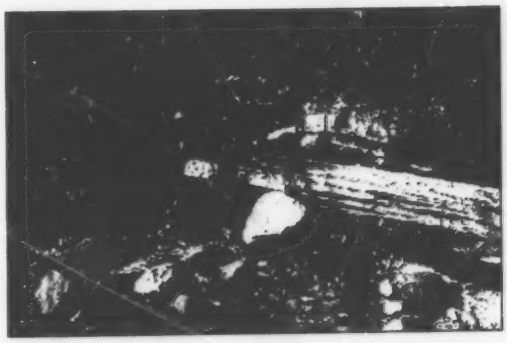

Figure 2–10. Downstream view of LWD/boulder complexes on the east and west bank (site 2).

Figure 2–11. Upstream view of LWD/boulder complexes on the east bank (site 2).

DEER CREEK GROUNDWATER POND

Objectives
The objectives of the Deer Creek Groundwater Pond project are to provide stable spawning and rearing habitat for salmonids, away from the tumultuous mainstem of the Chilliwack River.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Author
Jesse Brown

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Ministry of Environment, Lands and Parks, Ministry of Forests, Department of Fisheries and Oceans, and Forest Renewal BC.

Watershed/Stream
Chilliwack River/Deer Creek

Location
Deer Creek is located 10 km east of the Vedder Crossing on the Chilliwack Lake Road. The project site is located on the west bank of the Chilliwack River 4 km north on the Tamihi–Liumchen Forest Service Road.

Introduction
Deer Creek provides spawning and rearing habitat for chum, coho, chinook and steelhead. However, due to the ephemeral quality of the creek only the first 100 m were utilized by salmonids. The 1998/1999 project opens access to an additional 200 m of the creek, up to the Tamihi–Liumchen Forest Service Road. During a site visit on March 30, 2000 numerous salmonid carcasses and fry were observed in the 1998/1999 spawning/rearing ponds.

Assessments and Prescriptions
Historical logging in the Chilliwack River Watershed has resulted in significant flow events that have destroyed the complexity and stability of the main channel. Restoration projects have focused on side channels and tributary streams of the Chilliwack River, which offer protection from the destructive flows of the main channel (M.A. Whelan and Associates Ltd. and the Steelhead Society of BC, 1995).

Past Rehabilitation Work
In 1998/1999 a groundwater channel and pond complex was constructed in a seasonally wetted swale tributary to the south side of the Chilliwack River (Deer Creek). The groundwater channel, which connects to the Chilliwack River is only seasonally wetted. The completed project consisted of approximately 1500 m^2 of ponds over the 350 m length of the project.

Rehabilitation Work
Three ponds were excavated upstream of the logging road and each pond was connected by a raised riffle to prevent fish stranding (Figs. 2–12 and 2–13). The majority of the excavated material was end–hauled to the Slesse Creek R4 Road Deactivation project. Pond one is 80 m long by 10 m wide and up to 2 m deep. Pond two is 20 m long by 10 m wide and up to 2 m deep. Pond three is 10 m long by 10 m wide and 2 m deep. Forty pieces of large woody debris were added to the ponds to provide additional complexity. The pond excavation was completed using a Strohmaier Linkbelt 4300.

Cost Summary

Labour	$8,138
Equipment and Materials	37,208
Total Cost	$45,346

Outputs

Pond Area	1100 m^2
LWD	40 pieces

Production Estimates
The estimated coho smolt production for the two ponds is between 550 and 1100 for the estimated pond area of 400 m^2 (based on 0.5 to 1 smolt/m^2 of pond area (Koning and Keeley, 1997)).

Proposed Work
Riparian planting is scheduled for May 2000. Monitoring (including juvenile abundance and spawner counts) is also planned for 2000.

For Further Information

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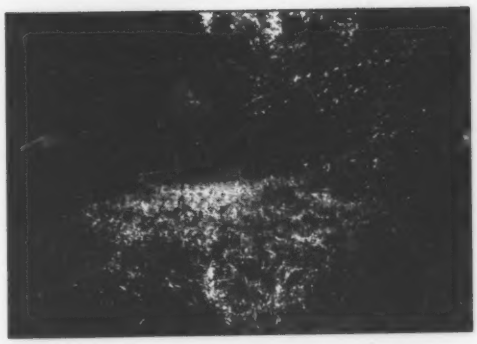

Figure 2–12. Deer Creek groundwater pond prior to excavation.

Figure 2–13. Deer Creek groundwater pond after work was completed.

CHILLIWA :K RIVER, MILLENNIUM PONDS

Objectives
The Millennium project is one of a series designed to create and restore productive off–channel spawning and rearing habitat for salmonids (coho, chinook, chum, pink, cutthroat and steelhead) in the Chilliwack River Watershed.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Matt Foy and Harold Beardmore

Proponent/Implementing Partners
Cattermole Timber and Resource Restoration Division, Fisheries and Oceans Canada.

Watershed/Stream
Chilliwack River/14 Mile Creek and 15 Mile Creek

Location
This project is located on the north side of the upper Chilliwack River between Nesakwatch and Centre Creeks.

Introduction
The Chilliwack River Watershed (dry maritime Coastal Western Hemlock (CWHdm) ecosystem) has been extensively logged since the early twentieth century. Most, if not all wild populations of salmonids, are presently below historical levels of abundance for reasons including logging–related habitat changes, agricultural and urban development.

Assessments and Prescriptions
Many of the side–channels in the 15 km section of the Chilliwack River below Chilliwack Lake were formed and historically received flow as a result of large logjams which caused river diversions. Streamside logging eliminated most of the large wood recruitment that was necessary to maintain these jams. As a consequence the river now flows in a single channel for much of this reach and many of its historic side–channels now only receive flow during extreme flood events. The restoration of year–round flow to these abandoned channels is a major goal of off–channel restoration in this part of the Chilliwack River.

Fourteen and 15 Mile Creeks are small tributaries on the north bank of the upper Chilliwack River. In the past, 15 Mile Creek flowed downstream in an ancient river side channel, joining and augmenting flow in 14 Mile Creek, before entering the Chilliwack River mainstem. Construction of the Chilliwack Lake Road isolated the two creeks from each other. A large, relic beaver dam obstructed upstream access to salmonids on 14 Mile Creek. Further upstream the creek flowed sub–surface under a talus slope.

Past Rehabilitation Work

Chilliwack Lake Outlet (1995)
2500 m^2 spawning gravel placement
Anderson Creek Pond (1995)
150 m^2 spawning and 15000 m^2 rearing
Centennial/Bulbeard (1996–1998)
15000 m^2 spawning and 95500 m^2 rearing
Angelwing (1997/1988)
2050 m^2 spawning and 11170 m^2 rearing
Yukalap (1997)
2000 m^2 spawning and 4400 m^2 rearing

Rehabilitation Work
Construction on this project occurred between July 27 and September 10, 1999. The contractor, Cattermole Timber, supplied a Cat 325 excavator, a 450 John Deere bulldozer with a six–way blade, and a Cat 250, articulated four–wheel drive, dump truck. The scope of the work included:

- Construction of a connecting channel between 14 Mile and 15 Mile Creeks. A rock groin diversion was constructed on 15 Mile Creek that diverts no more than one–third of the flow in to a settling/rearing pond. The pond was built by constructing a berm across an abandoned side channel of 15 Mile Creek. Water is diverted from the pond via a constructed spawning channel that runs adjacent to the Chilliwack Lake Road. This section was built next to the road to conserve a stand of large cedars and as an education and demonstration site.
- A 4–ft diameter arch culvert was placed under the Chilliwack Lake Road to convey flow from the 15 Mile Creek diversion, to 14 Mile Creek, through an old river channel.
- Approximately 100 m downstream, 14 Mile Creek flows subsurface under a talus slope. A spawning channel was built around this impasse to provide upstream access and to produce more spawning habitat (Fig. 2–14).

- A berm was built downstream of the talus slope, at the site of an old beaver dam. The berm brought the water in the pond up to historic levels, creating a large wetland. Woody debris was placed throughout the pond to create cover.
- A high gradient channel was built around the berm, to provide upstream access and also create more spawning habitat, in close proximity to deep cover (Fig. 2–15).
- A rock armoured by–pass spillway was constructed in the berm, at 1 ft above design water level. This will protect the berm from over–topping during a high water event or if a beaver dam creates a blockage at the spawning channel outlet.
- All exposed slopes were hand–seeded and mulched with hay to prevent erosion and to speed revegetation. One metre cedar trees were planted on the slopes of the berm.

Cost Summary

WRP (equipment and materials)	$87,000
DFO (design and supervision)	25,000
Total Cost	$112,000

Outputs

This project has created approximately 1500 m^2 of spawning habitat and 32000 m^2 of rearing habitat.

Production Estimates

16,000 coho and 400 steelhead smolts annually.

For Further Information

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Figure 2–14. Constructed spawning riffle with LWD and boulder cover.

Figure 2–15. Constructed berm with outlet spawning channel in centre.

SLESSE CREEK R1 GROUNDWATER POND

Objectives
The objectives of this project are to provide stable spawning and rearing habitat for salmonids by constructing a 400 m^2 pond with a small groundwater channel linking the pond to Slesse Creek.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Michael Engelsjord

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Ministry of Environment, Lands and Parks, Ministry of Forests, Fisheries and Oceans Canada, and Forest Renewal BC.

Watershed/Stream
Chilliwack River/Slesse Creek

Location
Slesse Creek is located 15 km east of the Vedder Crossing on the Chilliwack Lake Road. The project site is located west of the Chilliwack Lake Road Bridge over Slesse Creek on the south side of the creek.

Introduction
Slesse Creek has historically been a significant source for chum, coho, chinook and steelhead. However, escapements have declined dramatically over the last 20–50 years (Orr, 1995). Slesse Creek is stocked yearly with chum, coho, chinook and steelhead from the Slesse Creek FOC Hatchery; American Shad (*Alosa sapidissima*) were also, stocked in 1985 (MELP, 2000).

Assessment and Prescription
Historical logging to banks in the Slesse Creek Watershed has resulted in significant channel widening that have destroyed the complexity and stability of the main channel. Restoration projects have focused on side channels of Slesse Creek, which offer protection from the destructive flows of the main channel.

Past Rehabilitation Work
A groundwater channel (R4) was constructed on the east side of Slesse Creek in 1995/1996. This channel was extended a further 400 m in 1997.

Rehabilitation Work
Work began on July 27, 1999 and was completed on August 3, 1999. A 400–m^2 pond was excavated with a small groundwater channel linking the pond to Slesse Creek (Figs. 2–16 and 2–17). Approximately 1000 m^3 material was removed and transported to the Slesse Creek R4 Road Deactivation project. The pond banks are 2:1 and the pond ranges in depth from 0.2 to 2 m. Eighty pieces of LWD were added to the pond. Two riparian plots were planted with a total area of 40 m^2. The pond excavation was completed using a Strohmaier Linkbelt 4300.

Cost Summary

Labour	$4,300
Equipment and Materials	2,017
Total Cost	$6,317

Outputs

Pond Area	400 m^2
LWD	80 pieces

Production Estimates
Based on bio–standards provided in Koning and Keeley (1997) estimated coho smolt production for the two ponds is between 200 and 400 based on an estimated pond area of 400 m^2 (based on 0.5 to 1 smolt/m^2 of pond area). Estimated length of this pond is 0.1 km.

Proposed Work
All work scheduled for Slesse Creek Groundwater Pond was completed in the 1999/2000 season.

For Further Information

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Figure 2–16. Slesse Creek groundwater channel prior to excavation.

Figure 2–17. Slesse Creek groundwater channel after work was completed.

SLESSE CREEK R4 ROAD DEACTIVATION AND PONDS

Objectives
The objectives of the Slesse Creek Road Deactivation Project are to provide stable spawning and rearing habitat for salmonids, to reduce sedimentation into Slesse Creek from road runoff and to block vehicle access to the floodplain immediately adjacent to Slesse Creek and a productive restoration project.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Daniel Kochli

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Ministry of Environment, Lands and Parks, Ministry of Forests, Fisheries and Oceans Canada, and Forest Renewal BC.

Watershed/Stream
Chilliwack River/Slesse Creek

Location
Slesse Creek is located 15 km east of the Vedder Crossing on the Chilliwack Lake Road. The project site is located on the Slesse Forest Service Road/401, approximately 4 km upstream on the east side of Slesse Creek.

Introduction
Slesse Creek has historically been a significant source for chum, coho, chinook and steelhead. However, escapements have declined dramatically over the last 20–50 years (Orr, 1995). Slesse Creek is stocked yearly with chum, coho, chinook and steelhead from the Slesse Creek FOC Hatchery; American Shad were also stocked in 1985 (MELP, 2000).

Assessment and Prescription
Historical logging in the Slesse Creek Watershed has resulted in significant flow events that have destroyed the complexity and stability of the main channel. Restoration projects have focused on side channels of Slesse Creek, which offer protection from the destructive flows of the main channel. The deactivation of the road adjacent to the Slesse Creek 1995 side channel provided an opportunity to increase the available fish habitat and to plant a riparian zone to promote stability in the Slesse Creek floodplain.

Past Rehabilitation Work
A groundwater channel (R4) was constructed on the east side of Slesse Creek in 1995/1996. This channel was extended a further 400 m in 1997.

Rehabilitation Work
Work began on August 4, 1999 and was completed on August 9, 1999 (Figs. 2–18 and 2–19). A cross ditch was created at 10 m to prevent vehicle access to the restored site. The road surface was scarified, seeded and planted with alder whips from 10 m to 380 m where another cross ditch was installed. A culvert was removed at 70 m and three ponds in series were created (250 m^2). A second culvert was removed at 310 m and two ponds (50 m^2) were added. Thirty pieces of LWD were added to the five ponds and gravel/boulders were salvaged from the excavated material to line the ponds. All planting was done by hand. The pond excavation and road scarification was completed using a Strohmaier Linkbelt 4300.

Cost Summary

Labour	$3,863
Equipment and Materials	5,822
Total Cost	$9,685

Outputs

Pond Area	300 m^2
LWD	30 pieces
Estimated Length of ponds	0.06 km

Production Estimates
Based on bio–standards provided in Koning and Keeley (1997) estimated coho smolt production for the two ponds is between 150 and 300 based on an estimated pond area of ~300 m^2 (based on 0.5 to 1 smolt/m^2 of pond area).

Proposed Work

All work scheduled for Slesse Creek Road deactivation was completed in the 1999/2000 season.

For Further Information

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Figure 2–18. Slesse Creek road prior to deactivation at 70 m.

Figure 2–19. Slesse Creek road post–deactivation at 70 m.

FORESTRY CREEK GROUNDWATER CHANNEL AND PONDS

Objectives
The objective of this project is to create and restore productive off–channel spawning and rearing habitat for salmonids.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Matt Foy and Harold Beardmore

Proponent/Implementing Partners
Interfor and Resource Restoration Division, Fisheries and Oceans Canada.

Watershed/Stream
Indian River/Forestry Creek

Location
The west bank of the Indian River, between 8 and 9 km on the mainline forest service road.

Introduction
The Indian River Watershed has been extensively logged since the early twentieth century. Constructing the hydroelectric transmission line and gas pipeline also negatively affected the watershed. Salmonid populations are presently well below historic levels.

Assessments and Prescriptions
Many of the side channels and tributaries of the Indian River have been degraded by a variety of activities, including logging. To mitigate some of the loss of productive capacity, a site for construction of a groundwater channel/pond complex was identified. The site chosen was protected from floods of the Indian River by the Forest Service Mainline Road and was located in a BC Hydro transmission line right–of–way, to reduce riparian impacts. Benefits from the work are expected primarily to affect chum and coho salmon, and steelhead trout.

Rehabilitation Work
The project was constructed between July 27 and August 26, 1999. The contractor supplied a Cat 225 excavator, a 966 Cat loader and a dump truck. The scope of the work included:

- Clearing the channel alignment and stacking the downed wood for future use.
- Cutting a narrow trench (3 ft wide) to grade in order to lower the water table and dry out the majority of the material to be removed.
- Cutting the channel to the cross–sectional design and spreading the excavated material in the right–of–way (Fig. 2–20).
- Excavating deep ponds throughout the channel to create cover (Fig. 2–21).
- Placing the stockpiled wood throughout the channel and ponds.

Cost Summary

WRP (materials and equipment)	$52,000
DFO (project design and supervision)	6,000
Total Cost	$58,000

Outputs
2000 m^2 of spawning habitat and 3400 m^2 rearing habitat.

Production Estimates
500,000 chum fry and 3400 coho smolts

For Further Information

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Figure 2–20. Groundwater spawning riffle (constructed under BC Hydro right–of–way).

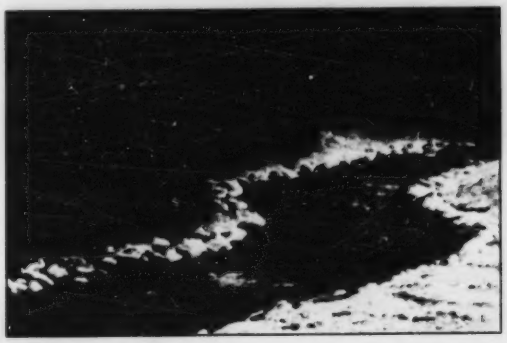

Figure 2–21. Lower rearing pond (under construction).

NAHATLATCH RIVER HABITAT IMPROVEMENT PROJECT
STRUTZEL POND COMPLEX

Objectives
To develop an enhanced channel/pond complex by providing a stable water supply with year–round fish access to the river, install structures and create stable spawning channels.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
P. Cochrane, Eng. Tech., Patricia Carlson, Eng. and M. Flynn, Bio.

Proponent/Implementing Partners
Fisheries and Oceans Canada, Habitat and Enhancement Branch, MELP, WRP, J.S. Jones, Keery Forestry, and Boothwroyd Indian Band.

Watershed/Stream
Nahatlatch River

Location
The project is located between km 17 and 18 on the Nahatlatch Forest Service Road, approximately 17 km west of North Bend, BC.

Introduction
The Nahatlatch River supports significant numbers of chinook, coho, sockeye and pink salmon, as well as steelhead trout, rainbow trout, and other fish species. A general degradation of habitat, particularly off–channel and overwintering habitat, is considered to be a contributor to the general decline of sensitive anadromous stocks in the system.

Assessments and Prescriptions
A series of existing ponds located at km 17, were seasonally isolated from the Nahatlatch River by a perched culvert and an intermittent water supply (Fig. 2–22). Assessment of these ponds indicated salmonids occupied only the lowermost pond. After further reconnaissance of the area, it was decided to develop an enhanced channel/pond complex by providing a stable water supply with year–round fish access to the river, and install structures such as pools complexed with rock and woody material and create stable spawning channels.

These habitat developments will significantly improve the availability of stable off–channel and overwintering habitats, critical for coho, chinook, steelhead and resident salmonid species. This enhancement project was developed in cooperation with the major landowner, Keery Forestry, as well as with BC Assets and Land Corporation, which control a portion of the Crown Land.

Rehabilitation Work
Fish habitat improvements were carried out along an 1120–m long complex adjacent to the Nahatlatch Forest Service Road and the Nahatlatch River, through a water surface gradient of 11.4 m. Construction took place during February and March 2000. The following was carried out:

1. Installation of a concrete intake structure and 60–m long by 600–mm diameter poly pipeline, to supply water from the Nahatlatch River.

2. Excavation of a 300–m inlet channel from the river intake pipe to a point where it can gravity feed into the remainder of the complex (Fig. 2–23). This channel was complexed with pools, and on–site rock and woody material, and will accommodate some spawning where in– situ substrate is adequate.

3. Excavation of a 90–m long by 2–m wide outlet channel, which directs flow to, and allows year–round juvenile and adult fish access to and from the complex and the Nahatlatch River. This channel was complexed with pools, and rock and woody material from on–site, and incorporates some low gradient sections for spawning. A large steel pipe arch culvert was installed to direct the channel under the road.

4. Backwatering of an existing pond, increasing the water surface by 0.7 m in elevation. As a result of the increased water surface elevation of this pond, the Nahatlatch Forest Service Road had to be raised by 1.0 m for a 75–m length (Fig. 2–24).

Outputs

Improvement	Area (m^2)	Length (m)
Inlet Channel	1840	460
Upper Pond	6930	420
Upper to Lower Pond Channel	240	120
Lower Pond	7380	500
Outlet Channel	270	90
Total	16660	1590

Cost Summary

DFO contribution (not including support costs)	$ 6,000
FRBC/WRP contribution through J.S. Jones	100,000
Total Cost	$106,000

Proposed Work

Additional habitat improvements are proposed for the fall of 2000, and include the enlargement of the upper pond section and addition of a 275–m long complexed channel.

For Further Information

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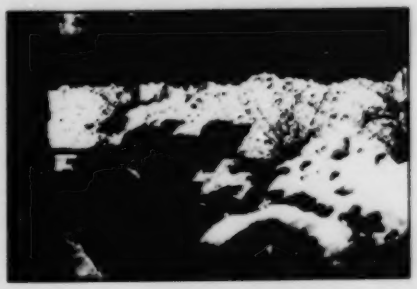

Figure 2–22. Downstream end of the project prior to construction, showing limited access through perched culvert to the Nahatlatch River. Under the rocks to the left of this culvert is a collapsed log culvert with some outflow to the river. This log culvert was removed to seal off the seepage through the road.

Figure 2–23. Excavator digging channel and loading material onto rock truck for disposal away from the right of way. Rocks, logs and stumps from on site were used to complex the channel.

Figure 2–24. Lower pond after construction, with Nahatlatch FSR on left. The road was built up 1 m to allow for an increase in the lower pond water surface by 0.6 m. A poly overflow culvert through the road is visible in the middle left of the figure.

SILVERHOPE RIPARIAN TREATMENTS

Objectives
The project objectives were to improve fish and wildlife habitat by accelerating conifer establishment, thus reducing the amount of time for LWD recruitment from areas of Silverhope Creek (Oikos Ecological Services Ltd. and T. Johnson and Associates, 1998).

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Michael Engelsjord

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Interfor, Ministry of Environment, Lands and Parks, Ministry of Forests and Forest Renewal BC.

Watershed/Stream
Fraser River/Silverhope Creek

Location
Silverhope Creek flows north from the Cascade Mountains and drains into the Fraser River near Hope, British Columbia. Treatment Units 1 and 2 are located near the confluence of Hicks and Silverhope Creeks adjacent to the 23 km marker on the Silver–Skagit Road. Treatment Unit 3 is located downstream of Treatment Units 1 and 2 adjacent to the 21 km marker on the Silver–Skagit Road.

Introduction
Silverhope Creek provides important habitat for coho, chum, pink, sockeye, steelhead, cutthroat (anadromous), and Dolly Varden. The upper reaches of Silverhope Creek are laterally and vertically unstable and have a high sediment load from [illegible]

Assessments and Prescriptions
The development of the deciduous overstorey and understorey resulted in poor site conditions (e.g. low light levels, lack of heat and growing space) for conifer regeneration and growth. The species composition of the riparian zone and previous logging practices have resulted in decreased complexity and increased instability in the Silverhope Creek mainstem. Planting grand fir (*Abies grandis*) and western red-cedar (*Thuja plicata*) was recommended to accelerate future recruitment of LWD and thereby increase habitat complexity and bank and channel stability (Oikos Ecological Services Ltd. and T. Johnson and Associates, 1998).

Past Rehabilitation Work
In Treatment Units 1, 2 and 3 (Treatment I) canopy gaps (openings) were cut in the deciduous overstorey and understorey (4.5 m radius) around each treatment centre (Oikos Ecological Services Ltd. and T. Johnson and Associates, 1998). This removal resulted in the reduction of approximately 25% of the deciduous overstorey. In Treatment Unit 3 (Treatment II) 70% of the deciduous overstorey was removed. Conifers were planted at a density of 15 seedlings (1.5 m triangular spacing) per treatment gap in Treatment Units 1, 2 and 3 (Fig. 2–25). Planting focused on naturally raised microsites. Spacing between treatment centres is 15.5 m, on average (Oikos Ecological Services Ltd. and T. Johnson and Associates, 1998).

Rehabilitation Work
Work began on May 1 and was completed on September 24, 1999. During 1998/1999 canopy gaps (4.5 m radius) were brushed, thinned and fill planted. Sites were fill planted with 540 cedar (DCK 0132 CW 415B 31947). A crew from New Forest Opportunities Ltd. brushed and thinned using machetes, grass whips and brush saws (Fig. 2–26).

Cost Summary

Labour	$27,441
Equipment and Materials	15,214
[illegible]	$42,655

Brushed and thinned	10.3 ha
Fill planted	540 seedlings

Proposed Work

All prescribed work was completed during the 1999/2000 field season.

For Further Information

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Figure 2–25. Western red–cedar seedling.

Figure 2–26. [illegible] site 1.

SQUAMISH WATERSHED REHABILITATION PROJECTS
ASHLU RIVER CHANNEL COMPLEXES AND BAR REVEGETATION

Objectives
The objectives for the Ashlu River project are to recruit LWD in a logjam formation and colonize gravel bars with riparian vegetation in order to reduce the adverse effects of high flow periods.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Karl Wilson

Proponent/Implementing Partners
Steelhead Habitat Restoration Corporation and Forest Renewal BC.

Watershed/Stream
Squamish River/Ashlu River

Location
The Ashlu Creek is a fifth–order coastal system lying approximately 28 km north of Squamish, BC, where it drains into the Squamish River.

Introduction
Logging on the Ashlu Creek alluvial fan has resulted in lateral channel shifts due to loss of bank cohesion. The current main channel is still very unstable and the quality of the fish habitat is poor.

Assessments and Prescriptions
The assessment of the Ashlu River indicates that high volume flows combined with poor bank stability and high sediment loads result in dewatering of productive side channels, destruction of spawning beds, and destruction of rearing habitat. In order to reduce the impact of high flow events it is necessary to create stable bars and encourage LWD recruitment. To achieve stability LWD/boulder complexes were to be placed on lateral bars south of the south side channel project and cottonwoods were to be planted.

Past Rehabilitation Work
Diversion and intake construction was carried out in August and September 1997 to re–water remnant side channels. South Channel construction was carried out in October and November 1997. North Channel construction was carried out in February and March 1998. Site clean up and revegetation was carried out in March 1998. The North Channel was watered in April 1998 (M. Brown, pers. comm., 2000).

Rehabilitation Work
Restoration work began September 22, 1999 and was completed on October 21, 1999. LWD/Boulder complexes were placed at three sites, designed to recruit LWD and built with the toe anchored facing upstream and the crib weighted down with cabled boulders. The first site was south of the intake for the Ashlu south channel project along the outside bend of the east bank. The second and third sites were near the edge of the lateral bar 0.25 and 0.5 km south of the first site (Fig. 2–27). The bar was planted with cottonwood stakes in a V pattern facing upstream. LWD was salvaged from the Interfor Helicopter landing site in TFL 38 (Fig. 2–28). The LWD/boulder complexes were constructed using a Cat 225 backhoe.

Cost Summary

Labour	$ 4,800
Equipment and Materials	17,358
Total Cost	$22,158

Outputs

Stream Bank Work	Increased LWD recruitment
Riparian Work	1.5 km

Proposed Work
All restoration work was completed on Ashlu River during the 1999/2000 season

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Figure 2–27. Site 2 LWD/Boulder recruitment complex.

Figure 2–28. Cottonwood whips planted to stabilize lateral gravel bars.

HIGH FALLS CREEK GROUNDWATER CHANNEL ALCOVE

Objectives
The project objectives at High Falls Creek were to stabilize the banks around the groundwater channel and to increase rearing habitat by creating an alcove and patching a small gap between the end of the berm and a spoil pile.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Karl Wilson

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation and Forest Renewal BC.

Watershed/Stream
Squamish River/High Falls Creek

Location
High Falls Creek drains two peaks on the east slopes of the Squamish River valley and flows south–southwest from the headwaters for 10 km prior to entering the Powerhouse channel at Mile 21 of the Squamish River Mainline Road.

Introduction
High Falls Creek provides significant spawning and rearing habitat for coho, chinook, pink, chum, steelhead and cutthroat trout. High Falls Creek, reach 2, is susceptible to braiding as the result of a high bedload (Steelhead Society Habitat Restoration Corp., 1996). A groundwater channel, 140 m long and 5 m wide, was constructed in 1996 to provide stable spawning and rearing habitat.

Assessments and Prescriptions
The assessment of High Falls Creek determined that the slope of the berm along the west and northern end of the channel was greater than 65°, which could become unstable. High Falls Creek was eroding the west side of the berm, therefore it required patching. Material to fill the berm was to be taken from the east side of the channel and the resulting hole would be turned into a 2 m deep alcove that would provide supplemental spawning and rearing habitat.

Past Rehabilitation Work
The High Falls Creek side channel was created in 1996 in order to provide stable spawning habitat for salmonids, specifically coho.

Rehabilitation Work
Work began on September 21, 1999 and was completed on October 15, 1999, an excavation total time of 4 days. Gravel was excavated from available deposits on the east side of the groundwater channel. The gravel was used to fill the west and north end of the berm. The berm was reshaped where the gradient exceeded 45°; excess material was used to shore up other areas of the berm. The hole adjacent to the groundwater channel was turned into an alcove with a depth up to 2 m. The alcove connects to the groundwater channel 25 m from the start of the channel on the east side (Fig. 2–29). Twenty pieces of LWD were added to the alcove to provide cover and temperature control for salmonids (Fig. 2–30). The work was completed using a Cat 225 backhoe.

Cost Summary

Labour	$ 4,088
Equipment and Materials	7,998
Total Cost	$12,086

Outputs

Alcove	450 m^2

Production Estimates
Creation of an alcove 450 m^2 could result in the additional production of 180 coho smolts and 121,500 chum fry (Koning and Keeley, 1997).

Proposed Work
All work was completed during the 1999/2000 season. Monitoring is planned for the as–built project. It will involve juvenile abundance and spawner counts.

For Further Information

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Figure 2–29. Outflow from the alcove into the High Falls Creek side channel.

Figure 2–30. North end of the High Falls Creek alcove with LWD.

SHOP CREEK GROUNDWATER CHANNEL

Objectives
The construction of a groundwater channel along Shop Creek would provide valuable rearing habitat for coho salmon and cutthroat trout juveniles.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Karl Wilson

Proponent/Implementing Partners
Steelhead Habitat Restoration Corporation and Forest Renewal BC.

Watershed/Stream
Squamish River/Shop Creek

Location
Shop Creek is a tributary of the Elaho River and is located near Mile 37 of the Squamish River Mainline.

Introduction
Shop Creek provides important spawning and rearing habitat for coho salmon and cutthroat trout juveniles. It has been the site of numerous restoration projects and Shop Creek enters the Elaho River just west of its confluence with the Squamish River. Shop Creek drains an area of approximately 3 km^2 (Steelhead, 1999).

Assessments and Prescriptions
Assessment of lower Shop Creek determined that an existing dry channel could be enlarged to create a productive spawning and rearing channel for coho and cutthroat trout. Groundwater existed close to the bed of the dry channel and, therefore, a groundwater channel could be created that remained wetted all year.

Past Rehabilitation Work
Habitat restoration has been ongoing in the Shop Creek Watershed since 1993. An overwintering pond was constructed in 1993. LWD was added to Shop Creek during 1993, 1994 and 1995 to provide cover and increase complexity within the stream channel.

Rehabilitation Work
Restoration work began September 21, 1999 and was completed on October 25, 1999.

A groundwater channel 22,500 m^2 was excavated running north/south along an existing swale. The channel connects to a previous pond/channel restoration complex before flowing into Shop Creek 0.2 km upstream from the Elaho River Mainline. The channel is wetted year round with a depth of 2 to 3 m (Fig. 2–31). Sixty pieces of LWD were added to the channel complex (Fig. 2–32). An old skidder track provided access to the site for the Cat 225 backhoe, Cat 966 loader, lowbed and dump truck.

Cost Summary

Labour	$17,226
Equipment and Materials	97,965
Total Cost	$115,191

Outputs

Groundwater Channel	22,500 m^2
LWD	60 pieces

Production Estimates
The Shop Creek restoration project could produce an estimated 9000 coho smolts and 6,075,000 chum fry (Koning and Keeley, 1997).

Proposed Work
All restoration work was completed on Shop Creek during the 1999/2000 season.

For Further Information

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Figure 2–31. Shop Creek groundwater–fed overwintering pond with LWD.

Figure 2–32. Shop Creek groundwater channel with LWD.

28.5 MILE CREEK OVERFLOW SPILLWAY MODIFICATION

Objectives
The objectives of the 28.5 Mile Creek project were to eliminate seasonal water loss at the overflow spillway, reduce entrained fines from entering the creek and provide cover for all salmonids.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Karl Wilson

Proponent/Implementing Partners
Steelhead Society Habitat Restoration Corporation, Ministry of Environment, Lands and Parks and Forest Renewal BC.

Watershed/Stream
Squamish River/28.5 Mile Creek

Location
28.5 Mile Creek enters the east side of the Squamish River near 28.5 Mile on the Squamish River Mainline.

Introduction
28.5 Mile Creek cuts the silt-laden floodplain of the Squamish River for 0.25 km before passing through a culvert under the Squamish River Mainline Road. Upstream 0.25 km from the culvert is a pond/channel complex that was initially created in 1991/1992 to increase salmonid spawning and rearing. 28.5 Mile Creek is approximately 1000 m long with a gradient of between 1 and 2% (SSHRC, 1999).

Assessments and Prescriptions
Assessment determined that the pond was seasonally subject to overflow during periods of heavy rain or snowmelt. The existing spillway was topped by angular rock, which allowed water to pass over the berm at high flows. The overflow entrained fines, which were transported back into 28.5 Mile Creek reducing the quality of the available fish habitat. The prescription advised that the overflow spillway should be raised to prevent water flowing onto the road.

Past Rehabilitation Work
Restoration began in 1993 with the creation of a channel/pool complex at the headwaters of 28.5 Mile Creek. Since 1993 several channel/pool and LWD complexes have been added (M. Brown, pers. comm., 2000).

Rehabilitation Work
Restoration work began on October 16, 1999 and was completed on October 23, 1999.

The overflow spillway was modified by removing a one metre wide section of angular rock (Fig. 2–33). Gravel was then added to raise the spillway by 0.6 m. The angular rock was then replaced on top of the spillway to inhibit erosion. The pond outlet was widened, by 2 m in order to reduce the chances of pond overflow via the spillway during future high flow periods. Sixty pieces of LWD were added to the channel/pond complex at 0.65 km (Fig. 2–34). Excavation was carried out by a Cat 225 backhoe. Gravel was transported from the excavation site at 36 Mile Creek. Pulp logs and rootwads were salvaged from the construction of the Interfor helicopter site, TFL 38, north of 36 Mile Creek.

Cost Summary

Labour	$ 438
Equipment and Materials	4,561
Total Cost	$4,999

Outputs

LWD (~0.1 km)	60 installations
Gravel	36 m^3

Proposed Work
LWD complexes downstream of the pond on 28.5 Mile Creek need to be completed. Monitoring of the as-built project is planned during 2000/2001, and will include juvenile abundance and spawner counts.

For Further Information

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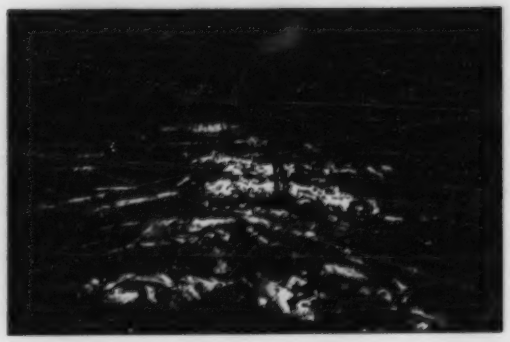

Figure 2–33. Raised overflow spillway adjacent to Squamish River Mainline Road.

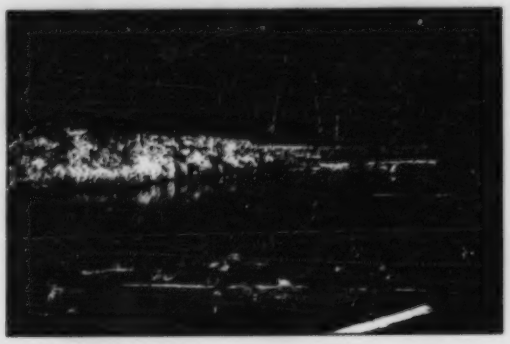

Figure 2–34. LWD placed in 28.5 Mile pond/channel complex.

36 MILE CREEK POND

Objectives
The objectives of the 36–Mile Creek project are to increase salmonid habitat by adding LWD/boulder complexes and raising the depth of the headwaters pond.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Jesse Brown and Karl Wilson

Proponent/Implementing Partners
Steelhead Habitat Restoration Corporation and Forest Renewal BC.

Watershed/Stream
Squamish River/36 Mile Creek

Location
36–Mile Creek is a tributary of the Squamish River located at Mile 36 of the Squamish River Mainline.

Introduction
36 Mile Creek is approximately 900 m in length and drains an area of 4 km^2. The riparian forest in the vicinity of 36–Mile Creek was logged in 1964. The floodplain is now dominated by deciduous forest. Beavers dammed large portions of the creek, limiting access to adult and juvenile salmonids and degrading spawning habitat (Steelhead, 1999).

Assessment and Prescription
The assessment of 36 Mile Creek indicated that changes in the pond from previous restoration projects had resulted in a lower mean depth and had therefore reduced potential rearing habitat. The prescription concluded that enlarging an overwintering pond by raising the outflow riffle and the overflow spillway would increase the overall depth of the pond by 0.5 m . The addition of LWD to the stream channel would increase the rearing capacity of the stream and increase the size of overwintering pools.

Past Rehabilitation Work
During September 1998 a berm was constructed to maintain an existing beaver pond and a channel was excavated to provide year–round fish passage between the pond and 36–Mile Creek (Steelhead, 1999).

Rehabilitation Work
Work began on September 23, 1999 and was completed on October 27, 1999. Gravel was excavated from available deposits at the east end of the berm, site of previous excavations. The gravel was used to raise the outflow riffle of the 36–Mile pond 0.5 m (Fig. 2–35). The overflow spillway was also raised 0.5 m (Fig. 2–36). The result was to increase the overall depth of the pond by 0.5 m and provide increased rearing habitat. The excavation and gravel placements were completed using a Cat 225 backhoe.

Cost Summary

Labour	$ 738
Equipment and Materials	16,426
Total Cost	$17,164

Outputs

Pond size increased	875 m^2

Production Estimates
Increasing the 36–Mile pond by 875 m^2 (~0.3 km) could result in additional production of 1050 coho smolts.

Proposed Work
LWD complexes downstream of the pond on 36–Mile Creek need to be completed. The LWD has been stockpiled on a skidder track adjacent to the creek.

For Further Information
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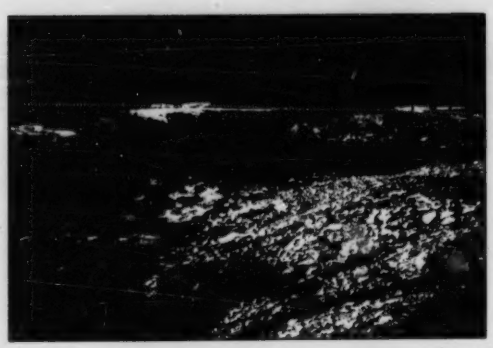

Figure 2–35. 36–Mile Pond raised outflow riffle.

Figure 2–36. 36–Mile Pond raised overflow spillway.

TZOONIE RIVER RIPARIAN RESTORATION

Objectives
The objective of this project was to speed the recovery of riparian function by manipulating and modifying the stand structure, density and species. The treatment area is within the 50–m riparian reserve zone and where feasible, the habitat was restored and or replaced for wildlife dependent on riparian ecosystems.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Author
Dennis Lozinsky

Proponent/Implementing Partners
International Forest Products Ltd., Kingcome Enhanced Forestry Division, Sechelt Indian Band, SIB Forestry Inc.

Watershed/Stream
Tzoonie River

Location
Tzoonie River flows into the head of Narrows Inlet. Narrows Inlet is 36 km north of Sechelt and is accessible by boat.

Introduction
The Tzoonie River drainage is approximately 182 km^2, and drains in a southwesterly direction into the head of Narrows Inlet. Tzoonie River currently provides habitat mainly for chum salmon. Populations of coho and pink have experienced a decline. The river also supports chinook and sockeye salmon, rainbow, steelhead and cutthroat trout, and Dolly Varden. Logging in the Tzoonie River has occurred since the early 1900s; the majority of the riparian forest was logged from 1940–1960. The riparian zone is primarily alder dominated with a young conifer understorey.

Riparian treatments are designed to restore riparian function by helping to speed recovery of mature forest characteristics. The treatments applied in the Tzoonie 50–m Riparian Reserve Zone (RRZ) are the first in the Sunshine Coast Forest District.

Riparian forest restoration has immediate and long–term benefits. Long–term benefits to riparian function are achieved by thinning high–density second growth to desired riparian densities. This treatment allows for the growth of conifers essential for maintaining the integrity of stream channels through stabilization and contributions to instream LWD. Treated riparian areas will result in wind from RRZ reducing risk of windthrow from future adjacent operational harvesting. For the short term, it can be argued that the creation of snags, habitat replacement for fur bearers, birds, bats, etc. create a link to old growth characteristics normally achieved over a long period of time. Currently, many of the RRZs are high–density, second growth stands that offer little or no habitat value. Second growth stands adjacent to the riparian zone are generally sterile environments lacking in wildlife habitat, sunlight, vegetation, coarse woody debris and snags.

Assessments and Prescriptions
Riparian treatments were identified as a priority from overview assessments carried out in 1997–1998, (Forrester, 1999). V.A. Poulin & Associates and Bart Simmons, Quillicum Forestry Services Ltd. developed detailed riparian prescriptions in July 1999. Field procedures were based on Koning, W., Editor (1998). The prescriptions identified 74.3 ha for treatment of which 47.9 ha were rated as high priority. Alder dominated riparian forest represent 83% of the prescribed high priority followed by 17% overstocked conifer stands.

Rehabilitation Work
Silvicultural treatments were carried out to speed recovery to old growth characteristics (Fig. 2–37).

The goal when treating overstocked stands (1000–3000/ ha) was to reduce crown closure to 20%, allowing for 40% sunlight to the forest floor.

Manual girdling (removal of the cambium layer in a 3–6 cm band around the bole of the tree) was the main treatment (Fig. 2–38) followed by felling. Riparian leave trees were selected on–site at densities of 300–500/ ha, and all deciduous trees were girdled within a 10–m radius of the riparian tree. Girdling offers the least risk of damage to the target riparian conifers. Girdled trees will die over a period of two years; the snags will eventually break apart with minimal damage to the remaining conifers. In comparison to alder dominated stands, overstocked conifer

stands offered greater opportunities for habitat restoration. Other treatments employed were top girdling, tree topping, placement of bird boxes for a variety of species, and creation of cavities for small fur bearers and bears.

Cost Summary

An 8–14 man crew was employed for 18 days.

Labour and supervision	$86,520
Transportation	9,180
Barge, accommodation, supplies, etc.	3,000
Total Cost	$98,700
Person–Days (PD)	302

Outputs

45.2 ha

Production Estimates

Alder girdling	0.3–0.5 ha/PD
Overstocked conifer	0.15–0.2 ha/PD
Average	$2183/ha

Proposed Work

Similar treatments are proposed for the Quatam River, on the Sunshine Coast.

For Further Information

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Figure 2–37. This conifer stand has been thinned and girdled.

Figure 2–38. This photo demonstrates the girdling of an alder.

ELIZABETH JOE GROUNDWATER CHANNEL

Objectives
The Elizabeth Joe Groundwater Channel is one of a series of projects designed to create and restore productive off–channel spawning and rearing habitat for salmonids (sockeye, coho, chum, cutthroat and steelhead) in the Upper Pitt River Watershed.

FRBC Region/MELP Region/MOF Region
Pacific/Lower Mainland/Vancouver

Authors
Matt Foy and Harold Beardmore

Proponent/Implementing Partners
J.S. Jones Ltd. and Resource Restoration Division, Fisheries and Oceans Canada.

Watershed/Stream
Upper Pitt River

Location
This project is located on the east side of Pitt River between 12 and 13 km on the mainline forest service road.

Introduction
The Pitt River Watershed has been extensively logged since the early twentieth century. Logging related activities have impaired the productive capacity of many side channels and tributaries. All wild populations of salmonids are presently below historical levels of abundance.

Assessments and Prescriptions
To mitigate some of this production loss, a groundwater channel site was identified. The primary fish species expected to benefit from the work are sockeye, coho, chum, cutthroat and steelhead.

Past Rehabilitation Work
Mosquito Creek Channel (1995)
100 m^2 spawning and 5900 m^2 rearing

Corbold Creek Channel (1997)
7000 m^2 spawning and 8700 m^2 rearing

Homestead Creek (1998)
750 m^2 spawning and 9750 m^2 rearing

Fish Hatchery Creek (1998)
200 m^2 spawning and 75000 m^2 rearing

Rehabilitation Work
The project was constructed between August 16 and September 15, 1999. J.S. Jones Ltd. supplied a Hitachi 200 excavator and a Cat 300 articulated four–wheel drive dump truck. The scope of the work included:

- The site for a 500 m long groundwater channel on Slough creek was identified.
- The channel alignment was cleared and the downed wood was stacked for future use.
- A narrow trench (1 m wide) was cut to grade in order to lower the water table and dry out the majority of the material to be removed.
- The channel was then cut to the cross–sectional design (2–3 m cut by 4 m wide) and the excavated material was spread in the right–of–way (Fig. 2–39).
- Groundwater flow generated from the channel was estimated at 3–5 cfs.
- Six gravel pads were installed throughout the channel to create short spawning sections and deeper pools upstream.
- Wood that was stacked during clearing and cedar found in landing piles along the road was then placed throughout the channel.
- Riparian areas adjacent to the channel were seeded with pasture mix and covered with hay to reduce erosion (Fig. 2–40). Cedars were also planted along the length of the project.

Cost Summary

Forest Renewal BC (Construction)	$100,000
Fisheries and Oceans Canada (Supervision and design)	25,000
Total Cost	$125,000

Outputs

The total channel area is 2000 m^2 with an estimated 30 m^2 of spawning habitat.

Length of the channel is 0.5 km approximately.

Production Estimates

The channel is expected to produce up to 3,000 sockeye fry and 2,000 coho smolts annually.

For Further Information

Contact

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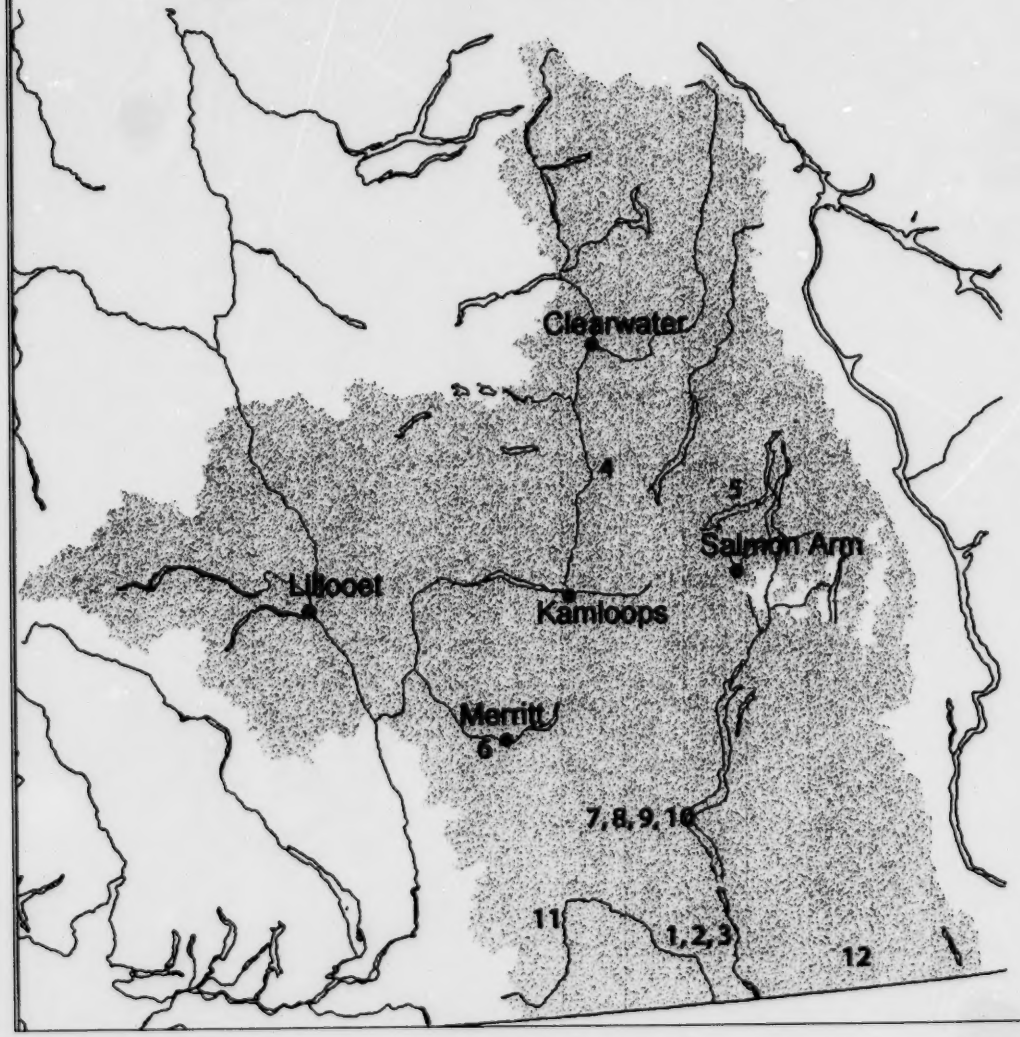
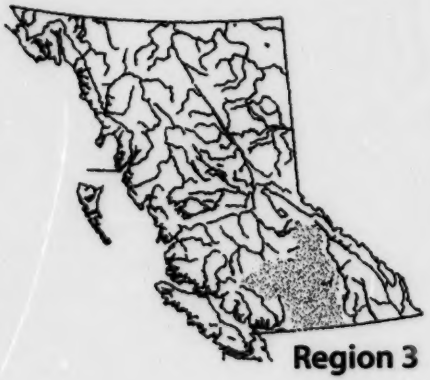
Figure 2–39. Constructed spawning riffle. Great care was taken to leave as many evergreen trees standing as possible.

Figure 2–40. Constructed pond. Banks were subsequently seeded and covered with hay, to prevent erosion.

Southern Interior Region

Region 3. Southern Interior





WRP Projects

1	Ashnola River
2	McBride Creek
3	Young Creek
4	Barriere River
5	Scotch Creek
6	Prospect Creek
7	Trout Creek
8	Tsuh Creek
9	Camp Creek
10	Crescent Creek
11	Arrastra Creek
12	West Kettle River

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 3, Southern Interior.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Southern Interior	Ashnola River	Ashnola River Bar Revegetation	11	5456734	283573	310-367800-37600	00000SIML
2		Ashnola River	McBride Creek Instream Restoration	10	5442716	696156	310-367800-37600-54700	00000SIML
3		Ashnola River	Young Creek Instream Restoration	10	5447400	699499	310-367800-37600-44700	00000SIML
4		Barriere River	Barriere River Off-channel Habitat	10	5673001	699968	129-190100	00000LNTH
5		Scotch Creek	Scotch Creek Bank and Bar Stabilization	11	5642405	324774	128-478700	00000SHUL
6		Spius Creek	Prospect Creek Instream Restoration	10	5541500	638510	120-246600-23400-39900	00000LNIC
7		Trout Creek	Trout Creek Streambank Stabilization and Bar Revegetation	11	5493459	310220	310-650900	00000OKAN
8		Trout Creek	Tsuh Creek Instream Restoration and Bank Stabilization	10	5509952	716143	310-650900-52700	00000OKAN
9		Trout Creek	Camp Creek Instream Restoration and Landslide Stabilization	10	5510299	715544	310-650900-53900	00000OKAN
10		Trout Creek	Crescent Creek Instream Restoration and Streambank Stabilization	10	5520692	712181	310-650900-85300	00000OKAN
11		Tulameen River	Arrastra Creek Streambank Stabilization	10	5476360	663284	310-367800-62000-25300-4600	00000ADMS
12		West Kettle River	West Kettle River Instream Restoration	11	5447874	356174	320-520100	00000KETL

ASHNOLA RIVER RESTORATION

Objectives

The objectives of this project were to decrease the input and transport of sediment from bank erosion; reactivate original channels using stream diversions; stabilize and complex stream channels for fish habitat; and accelerate riparian growth through planting.

FRBC Region/MELP Region/MOF Region

Thompson–Okanagan/Southern Interior/Kamloops

Authors

Dwight Shanner, R.P.Bio., Graham Martens

Proponent/Implementing Partners

Gorman Bros. Ltd., Ministry of Environment, Lands and Parks, and First Nations of the Okanagan Similkameen Environmental Protection Society (FNOSEPS).

Watershed/Stream

Ashnola River/Ashnola River, Young Creek, and McBride Creek

Location

The Ashnola River flows into the Similkameen River near Keremeos. The project areas were located on the Ashnola River approximately 17 km upstream from the confluence, Young Creek 6 km upstream from the confluence, and McBride Creek 150 m upstream from the confluence.

Introduction

The Ashnola River Watershed is designated as a community watershed and is used for domestic and irrigation water supply. Forest harvesting activities have been practiced over the past 60 years and cattle grazing through range tenures are active throughout the watershed. Several large sub–basins are designated as parkland within the Cathedral Provincial Park.

Resident rainbow trout occur throughout most of the watershed and are found in several lakes. Resident mountain whitefish occur within the Ashnola River but have not been found in the tributaries. In addition, westslope cutthroat trout (*O. clarki lewisi*) are found within the lakes and streams of the sub–basins that comprise Cathedral Park.

Assessments and Prescriptions

A channel assessment procedure was conducted in 1998 for the Ashnola River Watershed. Several proposed restoration sites from this report were reviewed by Randy Hardy (Gormans) and Phil Epp (MELP) with three sites prioritized for restoration works. Prescriptions were refined in the field with assistance from Phil Epp.

Rehabilitation Work

This project was completed between August 9 and November 25. There were three sites completed with nine individual tasks. All sites were planted with live willow stakes and seeded where appropriate. The work included:

- Ashnola River km 17: A large cobble side bar, approximately 30 m x 60 m, on the Ashnola River was not revegetating. The bar was excavated by machine to create 3 m x 3 m holes near the stream bank to a depth of 2 m. Live willow stakes, collected from the local area, were planted with a minimum of 15 stakes within each of the 17 excavated holes (255 total). Holes were backfilled partially by hand and completed by machine.
- Young Creek: Seven tasks were completed within 500 m of stream. At Task 1, a decaying wooden bridge was removed and two full spanning check logs were added to redirect flow, create pools for rainbow trout and reduce stream velocity. At Task 2, LWD was lifted from the top of a log jam and placed on the southeast streambank to stabilize the bank, provide roughness to water flow and create cover for fish. A rootwad and LWD was left in the channel to maintain fish habitat. Two trees, with defoliated branches, were added to a gravel bar near the north bank to act as debris catchers and sediment traps from the stream. A large rootwad was also added to the north bank near a large erosion site. At Task 3, an LWD jam and some deposited bed material was partially removed to allow Young Creek to flow down its original channel. The LWD was placed on top of the debris jam already located on the east bank gravel bar. A tree, with defoliated branches, was placed on the gravel bar where debris and sediments should be trapped during spring flooding (Fig. 3–1). A log diversion was constructed upstream of the avulsion to direct high flows into the original channel. Tasks 4, 5 and 6 were similar in nature and similar in treatment. Whole trees and logs were bundled and placed parallel to the streambank where rootwads would create "hard points" to deflect water flow away from eroding banks.

Each tree bundle was anchored by 1/2–inch galvanized cable to a deadman. The 250 m of streambank should provide bank protection and cover for fish when undercutting occurs. Live willow stakes were planted at Task 7 to the depth of the water table using a rotary powered hammer drill with a 1.5 inch auger bit 18 inch in length.

- McBride Creek: Numerous snags were felled around the work site for worker safety reasons and these provided LWD that was used for check logs and the diversion. An excavator was used to remove the berm that separated the existing channel from the original channel. Two full spanning check logs were added upstream of the diversion to dissipate energy prior to the diversion structure. A check log was also added downstream of the diversion as a gradient control structure.

Cost Summary

Labour	$19,668
Machinery and materials	10,332
Total Cost	$30,000

Outputs and Production Estimates

The project initiated the restoration of 700 m of stream. The area has the potential to produce an estimated 240 rainbow trout annually. A review of the restoration sites will be undertaken during and post–freshet 2000 to assess the overall effectiveness of the project.

For Further Information

Contact

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Figure 3–1. Young Creek avulsion deactivated and whole tree used for bar stabilization.

Figure 3–2. Whole tree revetments and willow planting along an eroding bank.

BARRIERE RIVER OFF–CHANNEL HABITAT DEVELOPMENT: PHASE 1

Objectives
The objectives were to increase stable off–channel habitat for rearing and freshet sanctuary for salmonids, particularly North Thompson River coho.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Authors
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Proponent/Implementing Partners
1. Tolko Industries Ltd. , Louis Creek Division
2. North Thompson Indian Band (NTIB)
3. ARC Environmental Ltd.
4. Summit Environmental Consultants Ltd.

Watershed/Stream
Barriere River

Location
The project is located approximately 20 km east of Barriere, near the Barriere Lakes Road crossing of the Barriere River. Access to the project, located upstream of the confluence of Barriere and East Barriere Rivers, is provided from the Barriere South Road.

Introduction
The importance of the Barriere River has been recognized by both provincial and federal agencies and the North Thompson Indian Band. Recent natural events in the watershed as well as anthropogenic activity have resulted in a reduction of off–channel habitat values. A 550–m long relic side channel of the Barriere River was identified as an ideal candidate for restoration. With improvements the off–channel would provide overwintering habitat that is important to maximize coho production, which is currently depressed in the Barriere River.

Assessments and Prescriptions
In 1998, ARC Environmental Ltd. under contract to Tolko Industries Ltd. conducted a watershed–scale survey of the Barriere River system to identify stream restoration options that would increase fish capacity of the system. During aerial reconnaissance, the off–channel site was identified. In 1999, Summit Environmental Consultants Ltd. conducted a geomorphic, hydrologic, hydraulic, and engineering assessment of the project site. A physical and biological monitoring program was initiated in conjunction with the North Thompson Indian Band. Following discussions with federal and provincial agencies, a construction plan was developed for the upper 250 m of side channel (Phase 1).

Rehabilitation Work
Construction was initiated in December 1999 and included:

- Fish salvage using a stop net at the downstream end of the site, baited minnow traps and an electroshocker;
- Construction of an access road. Trees removed along the road alignment were stockpiled for in–channel use;
- Excavation of a head–pond at the upper end of the site where groundwater inflows were measured;
- Sediment control at the lower end of the site involved the installation of hay bales, silt fencing and excavation of a sump and construction of a berm across the channel. Silt–laden water from the sump was pumped onto the floodplain to settle out;
- Excavation of the design channel was carried out on the first pass moving upstream (Fig. 3–3);
- Creation of habitat features (i.e. alcoves) and placement of woody debris and boulders was carried out on the second pass moving downstream; and
- Removal of sediment control measures at the downstream end of the site.

Equipment
- Case 9020B track excavator – Big Valley Trucking Ltd.
- Bulldozer – Big Valley Trucking
- Dump trucks – Big Valley Trucking
- Stihl 038 chainsaw
- Automatic level and stadia
- 2–in (31,000 L/hr) and 3–in (60,000 L/hr) centrifugal Tsurumi pumps
- Smith Root, 12B–POW electroshocker
- Minnow traps

Labour
- Overall project management, engineering design and reporting – Summit Environmental Consultants Ltd.
- Habitat design, fish salvage and environmental monitoring – ARC Environmental Ltd.
- Fish salvage and water quality and fish monitoring – North Thompson Indian Band

Materials

- Sand and gravel for access road
- 2 – 400 mm CMP culverts
- Hay bales and silt fencing for sediment control
- Woody material available on–site

Cost Summary

Professional fees (assessments, prescription development, and supervision)	$42,182
Labour and equipment	10,155
Materials	1,348
Total Cost	$53,685

Outputs

- 0.2 km and 500 m² of off–channel habitat created or enhanced
- 0.3 km of access road constructed

Production Estimates

The benefits of the project are associated with increases in production. For side/backchannel development the outputs are smolt production measured as no/m². The number of smolts produced in the channel can be compared either with pre–treatment values or with biostandards developed for similar habitat types. The Barriere River channel works were conducted during late fall when most fish had likely entered into the channel to overwinter. Even though fish have moved into newly created habitat the population is likely reflective of numbers of fish present before the works were done. Smolt trapping conducted in the spring of 2000 will provide an estimate of pre–project production. Monitoring in subsequent years will provide production estimates that can be compared to the 2000, or pre–project values. The output values (both pre– and post–project) will also be compared to biostandards for off–channel habitats in the interior of British Columbia. Outputs will be measured by trapping downstream migrating smolts in a fence located close to the outlet of the channel.

Proposed Work

Water quality and fish monitoring will be conducted through winter 1999/2000. Riparian planting and development of the lower portion of the channel, including the establishment of a stable connection to the Barriere River, is slated for year 2000.

For Further Information

Contact

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Figure 3–3. Initial excavation of off–channel habitat near lower end of project site.

BANK AND BAR STABILIZATION FOR SEDIMENT CONTROL IN THE EAST FORK OF SCOTCH CREEK

Objectives
The project objectives were to improve local water quality and habitat conditions for resident rainbow trout and to improve downstream water quality and habitat conditions for anadromous salmonids.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Authors
J. Bruce Runciman, R.P.Bio. and Alan Bates, P.Eng., Silvatech Consulting Ltd.

Proponent/Implementing Partners
Federated Co–operatives Ltd.

Watershed/Stream
Scotch Creek

Location
The East Fork of Scotch Creek includes all areas tributary to Scotch Creek above its confluence with Kwikwoit Creek, 14 km upstream of Shuswap Lake. The restoration activities described in this document are located in Reach 18 of Scotch Creek, between 16.8 and 21.6 km on the East Fork mainstem channel.

Introduction
Anadromous and freshwater game fish species known to occur in the Scotch Creek Watershed include sockeye, chinook, and coho salmon, bull trout (*Salvelinus confluentus*) and rainbow trout, kokanee, and mountain whitefish. Natural barriers in the lower mainstem limit fish distributions. Only obligate resident populations of rainbow trout have been confirmed to be present upstream of these obstructions, presumably having dispersed from stocked headwater lakes.

Dominant land uses in the East Fork of Scotch Creek include forest harvesting and road building, cattle grazing, and linear development in the form of a BC Hydro power transmission corridor. Other disturbances in the watershed include the 1967 Magna Bay fire.

Assessments and Prescriptions
An Overview Fish Habitat Assessment Procedure (OFHAP) was completed for the Scotch Creek Watershed during 1997. The OFHAP noted localized clearing of riparian vegetation, streambank instabilities, and extensive bar and sediment wedge formation in Reach 18 of Scotch Creek. The Channel Assessment Procedure for Scotch Creek further determined that Reach 18 had received increased sediment supplies from natural and development–related landslides and eroding banks. Channel bank and bar and riparian zone rehabilitation were recommended for several sites in Reach 18 of Scotch Creek following the stabilization of upslope areas.

Rehabilitation Work
Bar stabilization works at the three sites during October 1999, included the following tasks:

- A 10–person crew from the Adams Lake Indian Band cut and transported approximately 5,000 black cottonwood and willow live stakes to the work sites.
- At each site, a Schaeff HS 40 D walking excavator excavated narrow trenches across elevated bar deposits at a spacing of approximately 5 m and an upstream angle of approximately 5° from perpendicular to streamflow. The depth of individual trenches was sufficient to reach the groundwater table at time of construction. Live stakes were placed into the trenches at a downstream angle and an inter–stake spacing of 5–10 cm (Fig. 3–4). Each trench was then backfilled by the excavator to create a brush traverse. Hand crews subsequently completed live stake planting of sands and fine gravels between the brush traverses.

Bank stabilization works were initiated on October 30 and completed on November 3, 1999. The sequence of individual tasks was as follows:

- Two fisheries technicians from the Adams Lake Indian Band isolated the stream within the worksite and conducted multiple pass electroshocking to remove all fish present.
- A Hyundai 210 tracked excavator loaded gravel trucks with locally available boulders previously marked by the project biologist as meeting design criteria for prescribed structures. These were subsequently transported and stockpiled adjacent to the worksite.

- Trees previously marked by the project biologist as meeting structure design criteria were felled, limbed and bucked at the stump to design lengths and ground–skidded to the worksite by the Hyundai 210 excavator.
- The Hyundai 210 excavator and a three–person hand crew constructed three sections of log and rock revetment in a downstream to upstream sequence. Three pairs of boulders linked by epoxy–anchored galvanized steel cable held each section in place. Four LWD groins subsequently protected abutment points between revetment sections and the up– and downstream limits of the revetment (Fig. 3–5). Spacing between completed groins was approximately 12 m and each structure projected approximately 5 m into the bankfull channel. Each of the groins was 'pre–loaded' with the trimmed limbs of its structural members.
- Upon completion of instream works, banks were outsloped to 1:1. Riparian soils were laid over a single brush layer that projected over each section of log and rock revetment. All disturbed soils were grass–seeded and mulched with straw.

Cost Summary

Bar Stabilization Work Sites	
Design, Supervision	$5,900
Technical Support (labour)	11,000
Materials	100
Heavy Equipment	4,000
Subtotal	$21,000
Bank Stabilization Work Site	
Design, Supervision	5,000
Technical Support (labour)	4,000
Materials	600
Heavy Equipment	9,000
Subtotal	$18,600
Total Cost	$39,600

Rehabilitation Benefits

This project rehabilitated approximately 62 m of actively eroding streambank and 1700 m^2 of elevated sand and gravel bars. Local benefits to fish production are expected to occur as lateral scour pools develop with flow deflection around the completed debris groins. Benefits to fish production are also expected to result from reduced sediment loads in the mainstem channel of Scotch Creek. Total potential reductions in freshet–driven sediment load in Scotch Creek following bar stabilization treatments are estimated between 8500 and 15300 m^3.

For Further Information

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Figure 3–4. Downstream view of brush traverse and live stake planting.

Figure 3–5. Downstream view of ballasted LWD revetment and groin. Note the outsloped bank and brush layer in the foreground.

PROSPECT CREEK INSTREAM WORKS 1999

Objectives
The objective of this project was to reduce sediment impacts to Prospect Creek as a result of the creek eroding an adjacent trail. An adjacent, old channel was re–opened to balance instream hydraulics where the section of creek had moved up against the trail.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Author
Glenn Thiem

Proponent/Implementing Partner
Weyerhaeuser Canada Ltd., Merritt Branch.

Watershed/Stream
Spius Creek/Prospect Creek

Location
Prospect Creek is a small sub–basin located about 32 km on the TeePee Creek/Hochem Road, about 1 hr NW of Merritt. Prospect Creek is a tributary to Spius Creek.

Introduction
The Prospect Creek instream work was part of Weyerhaeuser's watershed restoration strategy for 1999–2000. Direction for restoration works was identified through an Overview Assessment (Henderson, 1999) and local Ministries. High fish and fish habitat values (including anadromous species) exist in Spius Creek, which includes a fish hatchery. An upstream migration barrier does limit anadromous species near the confluence of Prospect and Spius Creeks.

Assessments and Prescriptions
Prospect Creek was included in a Channel Assessment, Riparian Assessment and Sediment Source Survey. This work was reviewed and compiled to focus hillslope and instream prescriptions. Prescriptions were conducted by Merv Milligan and Associates Ltd. who identified numerous locations where bank instability problems were occurring along 216 m of Prospect Creek. All prescriptions to conduct instream work were approved by the Ministry of Environment, Lands and Parks.

Rehabilitation Work
The majority of the channel stabilization work was conducted from the existing trail adjacent to Prospect Creek. Channel stabilization involved about 330 m of fillslope pullback, re–contouring and 190 m of riprap (stream channel armoring). All pullback and re–contouring work was dry seeded with a grass mix.

Instream work was completed in phases. First, the old grown–in stream channel was assessed for the best entry and exit locations. Once these locations were identified, a work crew was brought in to clear the stream floor of vegetation.

A light excavator was brought into the old channel to clean out and restore the stream floor prior to diverting any hydraulic flows. The stream channel was engineered to balance out streamflows and reduce hydraulic energy occurring against the deactivated trail.

The last step was opening the entry way to start diverting flows into the restored channel. The entry way was designed with high water levels in mind. The restored channel will act more as a runoff channel to relieve hydraulic loading on the mainstem (Figs. 3–6, 3–7, 3–8).

Cost Summary

Labour	$ 1,000
Machinery and Materials	14,900
Total Cost	$15,900

Outputs
0.2 km of stream was restored.

Production Estimates
Although the purpose of the work carried out was to reduce sediment impact and erosion to the mainstem of Prospect Creek, the restored channel is supporting small fish species, as was identified a few days after construction. No formal measurement of production will be done, as it was not the main objective of this project.

Proposed Work

Bioengineering work of the deactivated section of road to the stream channel is scheduled for Fall 2000. Native shrub and tree species such as willow spp., northern black cottonwood and alder spp. will be planted on the site according to approved prescriptions.

For Further Information

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Figure 3–6. Post–construction, restored entrance.

Figure 3–7. Post–construction, restored mid–section of creek.

Figure 3–8. Post–construction, restored confluence of creek.

TROUT CREEK RESTORATION PROJECT

Objectives
The objectives of this project were to decrease the input and transport of sediment from bank erosion; to reactivate original channels using stream diversions; to stabilize and complex stream channels for fish habitat; and to accelerate riparian growth through planting.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Authors
Dwight Shanner, R.P.Bio. and Graham Martens

Proponent/Implementing Partners
Gorman Bros. Ltd., Riverside Forest Products Ltd., Ministry of Environment, Lands and Parks and First Nation of the Okanagan Similkameen Environmental Protection Society (FNOSEPS).

Watershed/Stream
Trout Creek/Trout Creek, Tsuh Creek, Camp Creek Tributaries, Crescent Creek

Location
Trout Creek flows into Okanagan Lake at Summerland. The project areas were located on Trout Creek approximately 24, 24.5, 25.5, 47, and 48 km upstream from the confluence; on Tsuh Creek 3 km upstream from the confluence, on Crescent Creek 300 m upstream from the confluence; and on Camp Creek tributaries (1 and 2) at the confluences.

Introduction
Trout Creek Watershed is designated as a community watershed with several reservoirs used for domestic and irrigation water supply for the District of Summerland. Forest harvesting activities have been undertaken over the past 60 years with selective cutting practiced historically and clear cutting at mid to high elevations being practiced over the past 30 years. The current ECA is estimated at 17%. Two large cattle ranches are located along Trout Creek, and cattle grazing is active throughout the watershed, through six range tenures. In addition, urban land use is prevalent along the lower reaches of Trout Creek.

Resident rainbow trout occur throughout most of the watershed, and eastern brook char (*Salvelinus fontinalis*) are found in some lakes and streams. Kokanee from Okanagan Lake spawn in the lower reaches and adfluvial rainbow trout from Okanagan Lake spawn in the lower and mid reaches of Trout Creek.

Assessments and Prescriptions
A Level 1 fish habitat and Proper Functioning Condition assessment were conducted in 1997 for Trout Creek Watershed. Several proposed restoration sites from this report were reviewed by Randy Hardy (Gormans), Paul McNamara (Riverside) and Phil Epp (MELP) with additional sites identified in the field. Nine sites were prioritized for 1999 restoration works. Prescriptions were refined in the field with assistance from Phil Epp.

Rehabilitation Work
This project was completed between August 9 and November 25, 1999. Thirty individual tasks were completed at nine sites. All sites were planted with live willow stakes and seeded where appropriate. The work included:

1. Trout Creek km 24: A 150–m long log revetment was used to decrease erosion at a meander bend. Whole trees and logs were placed parallel to the streambank creating "hard points" to deflect water flow away from eroding banks. Tree bundles were anchored using 5/8–inch galvanized cable to a log deadman 4 m from the bundle. Six anchored tree bundles were installed and the streambanks planted.

2. Trout Creek km 24.5: Riprap <1m was placed against the streambank (Summerland/Princeton Highway) for protection and used as turning rocks. Three logs were then driven almost vertically into the stream substrate to deflect flow away from the eroding site and provide fish habitat.

3. Trout Creek km 25.5: A 50–m long log revetment was used to decrease erosion at a meander bend. A tree was anchored to the eroding streambank using a deadman. Two additional trees were added to the eroding streambank but were not anchored in place. A second eroding bank had two natural deflectors at the upstream end. These natural rock and log deflectors were used as templates for prescriptions in addition to Lowe (1996). Three log deflectors were installed along the eroding bank creating a series of

five deflectors. Two bars were planted using a gas–powered rotary hammer drill with a 1.5–inch auger bit, 18– inches long, to excavate holes for willow cuttings.

4. Tsuh Creek: Twelve tasks were completed within 700 m. Several techniques were used at each site to achieve natural gradient control, sediment storage, and a decrease in streambank erosion. Four original channels were reactivated with the corresponding unstable avulsions deactivated. A culvert was removed and the road deactivated (Fig. 3–9); 35 full spanning check logs and 32 stone lines were added at natural channel frequencies. In addition, two upstream log V–weirs, four lateral debris catchers, and three log revetments were also constructed at this site.

5. Camp Creek Tributary 1: A lattice structure of woody debris was used to further stabilize two previous landslides. The lower reach was excavated by hand to mimic the upstream stable channel, then lined with cobbles and stone lines added. The channel banks were lined with log revetments and planted.

6. Camp Creek Tributary 2: A bed material blockage was excavated by hand from the original channel (10 m). The channel was then lined with cobbles, stone lines were added at natural cascade/pool frequencies, and a natural boulder weir was completed.

7. Trout Creek km 47: Four tasks were completed at this 250–m long site. Whole trees and logs were used at Task 1 to create log revetments. The placement of an upstream arch weir at Task 2 was constructed to decrease velocity, focus the water flow to the centre of the channel and create pool habitat. At Task 3, two log deflectors (Lowe, 1996) were installed on an eroding meander bend. At Task 4, a log revetment was constructed to support an eroding bank and direct flow towards the centre of the channel. Further downstream, two whole trees were added parallel to the streambank to help stabilize the bank.

8. Trout Creek km 48: A 100–m long log revetment was used to decrease erosion at a meander bend. Four tree bundles were anchored to deadmen. The streambanks were planted with live willow taken from the surrounding area.

9. Crescent Creek: Eight tasks were completed at the 350–m long site. An avulsion, approximately 30% of the water flow, was deactivated. The main channel was then stabilized to handle the natural streamflow. Whole trees, logs and rootwads were placed against eroding streambanks, five check logs were added, two SWD jams were removed and deactivation of the corresponding avulsions was undertaken. The small woody debris that was removed from the main channel was added to the overflow avulsions to create cover for fish.

Cost Summary

Labour	$71,420
Machinery and Materials	28,580
Total Cost	$100,000

Outputs and Production Estimates

The project initiated the restoration of 1900 m of stream. The area has the potential to produce approximately 650 rainbow trout annually. A review of the restoration sites will be undertaken in 2000 to assess the effectiveness of the project.

For Further Information

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Figure 3–9. Tsuh Creek culvert removed and stream rehabilitation undertaken.

ARRASTRA CREEK STREAMBANK STABILIZATION PROJECT

Objectives

The objectives of this project were to:

1. address current and prevent future channel avulsions within areas of riparian disturbance;
2. reduce the input and transport of eroded sediment downstream through the watershed; and
3. provide overwintering and rearing habitat for rainbow trout in association with channel stabilization initiatives.

FRBC Region/MELP Region/MOF Region

Thompson–Okanagan/Southern Interior/Kamloops

Author

Jan den Dulk

Proponent/Implementing Partners

Ardew Wood Products Ltd., Merritt, BC.

Watershed/Stream

Tulameen River/Arrastra Creek

Location

All works were completed within the main channel between 12 km and 14 km on the Arrastra Creek Forest Service Road, 50 km west of Princeton, BC.

Introduction

The Arrastra Creek Watershed drains an area of approximately 150 km^2. The watershed is located within the Montane and Engelman Spruce—Subalpine Fir biogeoclimatic zones. The mainstem flows from west to east and enters Granite Creek and eventually the Tulameen and Similkameen Rivers to join the Okanagan drainage. This area is primarily used for recreation and timber harvesting.

Rainbow trout populations are resident within the watershed. Habitat features have been limited by a combination of excessive erosion and downcutting of the main channel; the loss of LWD input to the creek; low summer flows; and sediment transport downstream through the watershed. The primary goals of this project were to stabilize the eroding bed and banks; protect the channel from existing and future lateral avulsions; re-establish hydraulic variability and restore instream LWD and cover features suitable for providing overwintering and rearing habitat.

Assessments and Prescriptions

Preliminary assessments were conducted to identify existing channel and habitat conditions and provide potential areas for restoration projects. Due to Fisheries' work window timing restrictions, prescriptions were refined in the field with assistance from P. Epp (MELP) and B. Taylor (MELP) and B. Hampton (Hampton Resource Management Services Ltd.) and then implemented during the 1999 work window.

Rehabilitation Work

All rehabilitation works completed were focused on the main objective of providing stable streambanks adjacent to a cutblock with no substantial riparian re-vegetation. All excavation and LWD placement was completed using a track excavator working from the top of the bank. Cedar, spruce and fir LWD was salvaged from a series of local burn piles and placed adjacent to the installation sites using a log truck and skidder. All LWD ranged from a minimum of 0.3 m to a maximum of 0.6 m diameter. Stock for bioengineering was collected adjacent to the work site a minimum of 50 m from the stream.

Five areas of vertical and sloughing banks were treated by excavating 2:1 slopes and constructing lateral structures using LWD revetments (Fig. 3–10). These consisted of one key log every 4 m along the bank anchored by its length (3 m) into and perpendicular to the bank. Additional logs were overlain on the key logs to build an interlocking matrix of LWD up to the observed bankfull elevation. Where required, logs were cabled together using galvanized cable and clamps to improve the integrity of the overall structure. Wattle fences and/or modified brush layers were constructed above this elevation utilizing native willow and cottonwood species. Live willow and cottonwood poles were also integrated into the matrix where appropriate.

Three aggrading lateral gravel bars were treated by burying live cottonwood poles (minimum 0.2 m diameter) into the water table, inclined 45° downstream and spaced 1 m apart. These poles occupy one-third of the bar area parallel to the natural streambank. Several pieces of LWD were placed perpendicular to the flow over the bar between the cottonwood poles to provide additional roughness and to create areas of local sediment deposition.

Wattle fences and/or modified brush layers were installed using crew labour at five locations where excavator access was limited (Fig. 3–11). These structures address local and small scale (<25 m^2) areas of bank instability by providing slope breaks and re–vegetation prescriptions.

One off–channel rearing pond was developed to provide refuge habitat for resident rainbow trout during summer low flow and/or freshet conditions where instream habitats are limited. LWD (rootwads) was added to the pond to provide approximately 40% cover.

All disturbed areas were re–vegetated using native willow and cottonwood whips and an interior erosion control native seed mixture formulated specifically for the local biogeoclimatic sub–zone.

Cost Summary

Excavator	$7,000
Skidder	1,000
Log Truck	1,000
Overall project management, technical design, environmental monitoring and reporting	4,000
Bioengineering technicians, WCB first–aid and general labour	7,000
Materials and supplies	3,000
Total Cost	$23,000

Outputs

0.3 km of channel bank work (stabilization), 0.1 km of riparian work (left bank) and 100 m^2 of instream work (bar stabilization) was completed. 0.10 km and 100 m^2 of off–channel rearing habitat was developed.

Proposed Work

None.

For Further Information

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Figure 3–10. Excavated bank and LWD matrix to stabilize eroding material.

Figure 3–11. Wattle fences installed using crew labour where excavator access was limited.

WEST KETTLE RIVER RESTORATION DEMONSTRATION SITE

Objectives

The objectives of this project are to provide a demonstration site for a variety of fish habitat rehabilitation techniques appropriate to large streams of the Interior for training courses; to provide opportunities for community–based employment, mentoring and stewardship; and to restore and protect fisheries and aquatic resources in a significant section of river.

FRBC Region/MELP Region/MOF Region

Thompson–Okanagan/Southern Interior/Kamloops

Authors

Pat Slaney, Wendell Koning and Daiva Zaldokas

Proponent/Implementing Partners

Ministry of Environment, Lands and Parks, Penticton (Phil Epp) and Pope and Talbot Ltd.

Watershed/Stream

West Kettle River

Location

The West Kettle river parallels Highway 33, approximately 65 km southeast of Kelowna. The demonstration site containing the installed instream and bank structures is located upstream and downstream of the confluence with Little Goat Creek; it is beside Highway 33, 16 km south of the town of Beaverdell.

Introduction

The West Kettle River (mean monthly discharge May–August, 57.9, 36.9, 12.0, and 3.9 m^3/s, respectively; max. daily discharge in May, 135 m^3/s; drainage area, 1870 km^2; bankfull channel width, approximately 30–40 m) has been affected by past logging activities, agriculture, road construction (Highway 33), and by the now defunct Kettle Valley Railroad.

Assessments and Prescriptions

Previous studies have provided estimates of resident rainbow trout population numbers and habitat capability in the West Kettle River and some of its tributaries. Historical data indicates low fish populations and limited fish habitat characteristics (lack of LWD and pools). For the past five years, the trout fishery has been managed largely under catch and release regulations, with potential for up to 40 cm fish in prime habitats.

Past Rehabilitation Work

Nine lateral log jams were installed within an 2.0 km section of river in 1996–97. These were of a triangular design that resists drag forces (Slaney *et al.*, 1997) and replicates natural lateral jam templates in trout rivers. These structures provide cover for fish and create scour–pools.

In September 1998, eleven additional structures were installed in the 2.0 km treated section: one additional lateral log jam, two sets of three bank stabilization structures, and four log box groins.

Rehabilitation Work

New structures installed in 1999 included two debris reef structures (designed by Rheal Finnigan), four triangular LWD/boulder complexes (Figs. 3–12, 3–13), and one bank debris groin. Work was completed with a Yutani 200 excavator and a backhoe. A 5–ton truck was used to haul boulders and rootwads. The purpose of the bank stabilization and debris reef structures are to provide additional fish habitat complexity and reduce bankside erosion. Previous structures consisted of hemlock logs and river boulders for ballast, but larch logs were used in 1999. The structures were installed such that they occupy less than 30% of the stream width and the debris reefs were installed to be submerged below the low water mark, in deep, wide pools near the stream bank. Maintenance work was conducted on four structures installed in 1998.

During the summer months, a creel census was carried out to survey the number of fishers and "catch per unit effort" within the treated reach.

Cost Summary

Labour — local	$1,500
Equipment and Materials[1]	4,500
Engineering and Biological Support	3,200
Total Cost	$9,200

[1]Attrill Woodworking Services, 2424 Enterprises, Beaverdell, BC.

Outputs

Structures were installed over a linear river distance of 0.5 km. This rehabilitated an estimated 15,000 m^2 of fish habitat in 1999, and 2.0 km in 1996 to 1998.

Production Estimates

Based on snorkel count results, the 1999 log–boulder structures are likely capable of supporting 5–10 catchable–sized rainbow trout each for a total of 35–70 fish. At 2 angler–days per fish, the additional catchable fish are therefore estimated to provide 70–140 angler–days.

Proposed Work

A more rigorous riparian assessment–restoration phase will be initiated in the spring of 2000, including planting of willows, cottonwoods and conifers, as well as bio–engineering treatment of a small eroding bank. Monitoring will be continued to assess condition and durability of structures, and to obtain more detailed data on fish abundance compared to a control reach.

For Further Information

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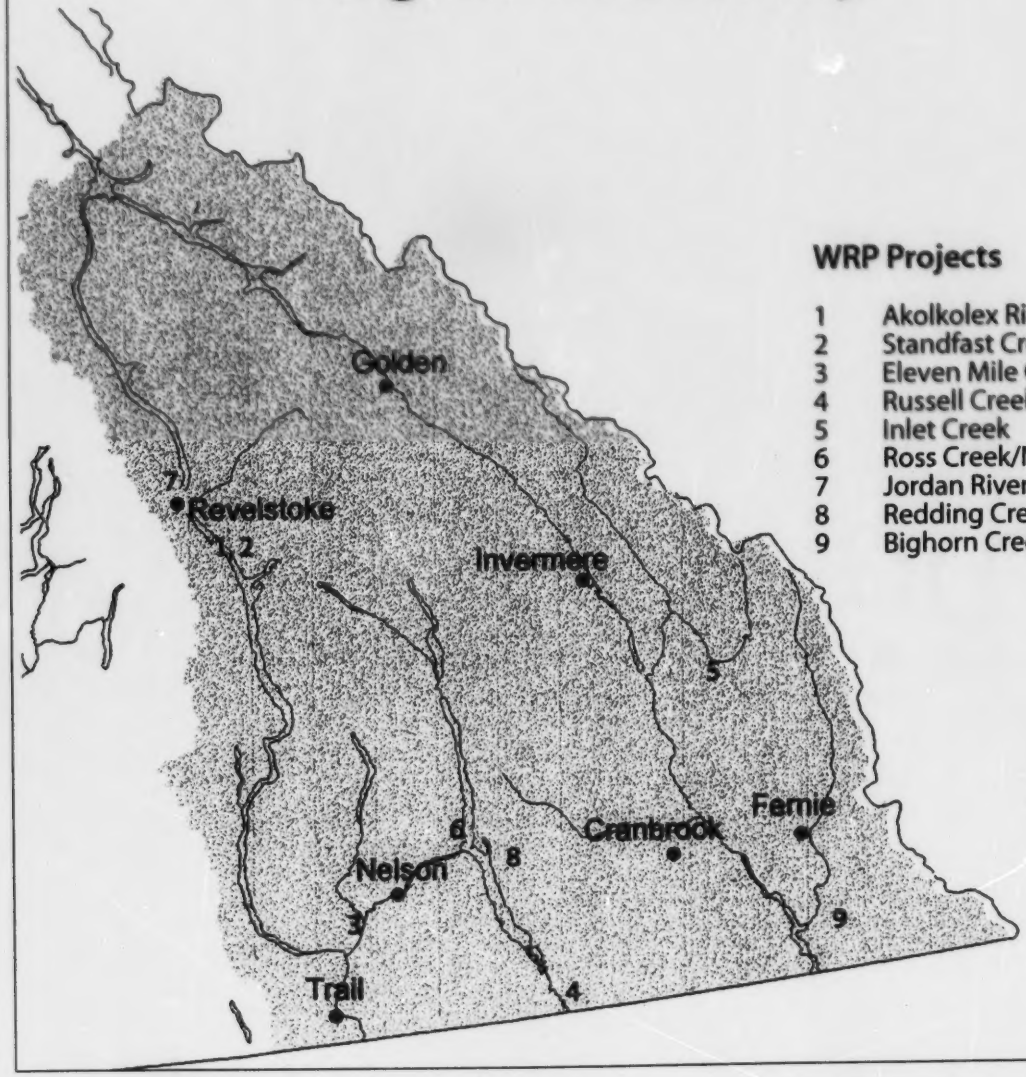
Figure 3–12. George Attrill cutting a notch in a log of a triangular LWD/boulder complex on the West Kettle River, 1999.

Figure 3–13. Heather Deal drilling a hole in a boulder of a triangular LWD/boulder complex on the West Kettle River, 1999.

Kootenay Region

Region 4. Kootenay



WRP Projects

1 Akolkolex River
2 Standfast Creek
3 Eleven Mile Creek
4 Russell Creek
5 Inlet Creek
6 Ross Creek/North Aylmer Creek/South Aylmer Creek
7 Jordan River
8 Redding Creek
9 Bighorn Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 4, Kootenay.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Kootenay	Akolkolex River	Akolkolex River Instream Restoration	11	5630729	427454	300-741700	00000UARL
2		Akolkolex River	Standfast Creek Bank Stabilization and Riparian Restoration	11	5640695	438268	300-741700-54300	00000UARL
3		Blueberry Creek	Eleven Mile Creek Instream and Riparian Restoration	11	5460597	440489	300-633000-48500	00000LARL
4		Goat River	Russell Creek Channel Rehabilitation	11	5445398	548037	340-445900-32100-04700	00000KOTL
5		Inlet Creek	Inlet Creek Instream Restoration	11	5555843	610104	349-666200-32000-34500	00000KOTR
6		Kootenay Lake	Ross Creek, North Aylmer Creek,	11	5500259	504933	340-212700	00000KOTL
			South Aylmer Creek Channel Restoration	11	5500259	504933	340-212700	00000KOTL
7		Jordan River	Jordan River Boulder Clusters	11	5651872	413211	300-754800	00000REVL
8		St. Mary River	Redding Creek/Trib. 780 Instream Restoration	11	5489503	529458	349-411700-55000	00000SMAR
9		Wigwam River	Bighorn Creek Instream Restoration	11	5449832	648633	349-248100-04900-37900	00000ELKR

AKOLKOLEX RIVER STREAMBANK STABILIZATION, BIOENGINEERING/ RIPARIAN RESTORATION AND SURFACE WATER INTAKE

Objectives

The objectives of this project were:

- to protect the fish and wildlife habitat complex developed at km 23.5 in 1997;
- to provide a new surface water intake for the km 23.5 fish and wildlife habitat complex;
- to restore riparian function at km 21 of the Akolkolex FSR.

FRBC Region/MELP Region/MOF Region

Kootenay–Boundary/Kootenay/Nelson

Author

Cory S. Legebokow

Proponent/Implementing Partners

Ministry of Environment, Lands, and Parks on behalf of Downie Street Sawmills Ltd. of Revelstoke, BC.

Watershed/Stream

Akolkolex River/Standfast Creek

Location

The Akolkolex River is located within the Columbia Forest District approximately 25 km southeast of Revelstoke, BC. It flows southwest for 31 km from its glacial headwaters in the Duncan Ranges of the Selkirk Mountains to its confluence with the Columbia River.

The watershed restoration works are clearly visible from the Akolkolex FSR at km 21 and km 23.5. The surface water intake is located at the downstream side of the Standfast Creek culvert at approximately km 24.

Introduction

The Akolkolex River Watershed (Northern Columbia Mountains eco–region; Interior Cedar–Hemlock biogeoclimatic zone) has a total drainage are of 395 km^2. It was one of the first valleys to be harvested within the Revelstoke TSA and had 29 cutblocks harvested prior to 1987, primarily along the mainstem valley bottom and lower reaches of the main tributaries.

The Akolkolex Watershed contains westslope cutthroat trout and slimy sculpins (*Cottus cognatus*). The population of westslope cutthroat is of particular interest because it has not experienced any degree of introgressive hybridisation with introduced rainbow trout as has occurred in many other watersheds (DeDominicis and Boag, 1996). The combination of previous forest harvesting practices and historical angling pressure is thought to have caused a decline of this provincially significant endemic population.

Assessments and Prescriptions

Both a Level 1 Fish Habitat Assessment Procedure (FHAP) and a Riparian Assessment and Prescriptions Procedure (RAPP) were completed for the watershed in 1996 and 1998, respectively.

Past Rehabilitation Work

A mitigation project developed off–channel groundwater fed winter rearing and spring high flow refuge habitat in the fall of 1997 (Zaldokas, Editor, 1998, 1999). The project created approximately 4200 m^2 of pond, pool, and riffle habitat types. A supplemental surface water source was added to the project in 1998.

Rehabilitation Work

The supplemental surface water source intake box installed in 1998 was buried during the spring of 1999 due to high bedload movement within Standfast Creek. As a result, a Fisheries Habitat Engineer designed a new intake box. The new intake box was installed on the downstream side of the culvert where the resultant scour maintains a stable pool. A new 130–m long section of 6–inch PVC pipe was connected to the existing pipe about half way along its length. An additional 130–m of socked perforated pipe was connected to the perforated pipe installed in 1998 in order to increase groundwater collection capacity.

The high bedload movement from Standfast Creek has also caused aggradation within the Akolkolex River, resulting in lateral channel migration and streambank erosion that was threatening the fish and wildlife habitat complex. Five lateral debris catchers were constructed to protect the fish and wildlife habitat complex and adjacent riparian vegetation. During construction there was log

breakage. Therefore the downstream debris catcher was modified into a triangular lateral logjam. All five structures will also serve to increase fish habitat complexity by creating lateral scour pools (Fig. 4–1).

The RAPP identified significant sediment sources from two over–steepened sections of road fill at approximately km 21 of the Akolkolex FSR (DeDominicis and Duane, 1998). Detailed bioengineering prescriptions were developed to restore riparian function. The bioengineering included the installation of live smiles, wattle fences, live pole drains, live brush layers, and live stakes (Raymond, 1999). In addition, two lateral debris catchers were constructed at the toe of one of the slopes in order to stabilize the streambank (Fig. 4–2).

Cost Summary

Labour	$32,300
Equipment and Materials	36,200
Total Cost	$68,500

Outputs

1. Approximately 40 litres/second of supplemental water were provided to the fish and wildlife habitat complex at km 23.5;

2. 0.20 km of right streambank were stabilized;

3. 0.14 km (0.37 ha) of riparian function along the right streambank was restored.

Production Estimates

Adult cutthroat trout spawned within the riffle portions of the inlet and outlet channels of the fish and wildlife habitat complex at km 23.5. Young–of–the–year (YOTY) were observed within these areas by the end of July. These YOTY were too numerous to count and were too small to electroshock effectively.

Cutthroat ranging from 10–40 cm were also observed within the pond portion of the complex throughout spring, summer and fall. Winter use has not been documented due to pond ice cover and poor site accessibility. It is estimated that the seven lateral debris catchers will result in a 2.3–fold increase in total fish numbers within the treatment area based on information presented in Koning and Keeley (1997).

Proposed Work

A perched culvert at km 26 of the Akolkolex FSR prevents fish access to a groundwater fed tributary. During 2000, the culvert will be replaced with a bridge and the channel length will be extended through the adjacent riparian area. In addition, three more lateral debris catchers are prescribed for the left bank of the Akolkolex mainstem at approximately km 24.

For Further Information

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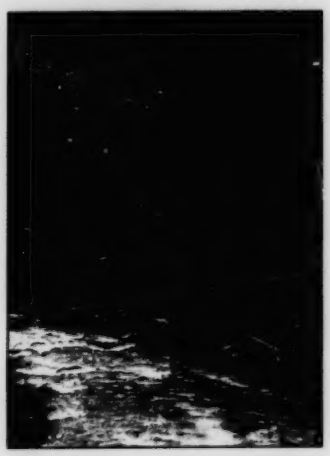

Figure 4–1. Upstream view of lateral debris catchers at km 23.5. The closest structure was modified to a triangular lateral logjam.

Figure 4–2. Bioengineering and lateral debris catchers at km 21 on the Akolkolex River Forest Service Road.

ELEVEN MILE CREEK
LARGE WOODY DEBRIS PLACEMENT AND RIPARIAN PLANTING

Objectives
The objectives of this project were to slow the movement of sediment through Eleven Mile Creek with the instream placement of large woody debris and to ensure a supply of LWD in the future by planting the riparian area.

FRBC Region/MELP Region/MOF Region
Kootenay–Boundary/Kootenay/Nelson

Author
Terry Anderson

Proponent/Implementing Partners
Atco Lumber Ltd.

Watershed/Stream
Blueberry Creek/Eleven Mile Creek

Location
Eleven Mile Creek is a tributary of Blueberry Creek that flows into the Columbia River 5 km south of Castlegar.

Introduction
Eleven Mile Creek is a second–order stream that flows north into Blueberry Creek. It has a step–pool (boulder/cobble) morphology for most of its length. The average channel slope is 16% and the total drainage area is 8.6 km^2. Extensive logging and road building occurred in the Eleven Mile Creek Watershed in the early seventies. Blueberry Creek, to which it is a tributary, is defined as a community watershed.

Assessments and Prescriptions
Numerous assessments and reports have been prepared about Blueberry Creek, which is a community watershed. Level 1 and 2 Road and Hillslope Assessments were conducted in 1996 by Kokanee Forest Consulting and EBA Engineering Consultants Ltd., respectively. An Interior Watershed Assessment Procedure was conducted by the Ministry of Forests the same year and a Channel Condition and Prescription Assessment in 1999 by Apex Geoscience Consultants Ltd. A paired Watershed Comparison by Klohn–Crippen (1999) and Restoration Guidelines for Eleven Mile Creek: Placement of Large Woody Debris (1999) refined the instream prescriptions.

Rehabilitation Work
A 500–m section of Eleven Mile Creek within an old cutblock was identified as being particularly lacking in functioning LWD. Consequently, the channel was unstable and sediment transported downstream more readily to the lower reaches of the community watershed. To remedy this, logs were flown in by helicopter and dropped on the bank. A chainsaw winch and hand tools were used to move the LWD into the wetted perimeter where it was cabled to native ballast in the streambed and on the bank using the HILTI™ epoxy method (Figs. 4–3, 4–4, 4–5). A very small footprint of disturbance was realized in the riparian area by using a chainsaw winch to position the LWD rather than a piece of heavy machinery (Fig. 4–6).

The LWD structures were constructed to retain sediment rather than to provide fish habitat. As sediment is retained upstream of the debris, sediment is conversely scoured from the downstream side resulting in the development of pools and the formation of a stepped channel.

The riparian area was infilled and planted with 2,986 hemlock (*Tsuga spp.*) seedlings early in the spring of 1999.

Cost Summary

Labour	$ 8,325
Machinery and Materials	13,534
Total Cost	$21,859

Outputs
0.50 km of stream was restored and 1.9 riparian hectares planted.

Production Estimates
The development of a step–pool profile in the tributaries of Blueberry Creek should slow the transportation of sediment and improve the overall water quality of the community watershed.

Proposed Work

Blueberry Creek has other tributaries that have been logged to the streambank and are deficient in LWD. Pending the results of this project they will undergo similar treatment.

For Further Information

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Figure 4–3. There is next to no functioning LWD in this 500–m section of Eleven Mile Creek. A chainsaw winch pulls the first piece into the wetted perimeter.

Figure 4–4. Obviously satisfied with his work, this forest worker displays his chainsaw winch, the piece of equipment used to drag the LWD into place.

Figure 4–5. Large woody debris cabled to bedrock in Eleven Mile Creek using the Hilti™ epoxy method.

Figure 4–6. Large woody debris was added to this section of Eleven Mile Creek to provide structure and promote a step–pool profile. Note that there are no large conifers in the riparian area and that sediment has been scoured from the stream channel.

RUSSELL CREEK CHANNEL REHABILITATION

Objectives
The objectives of this project were to block off several channel avulsions down an old forest road thereby returning the flow of water to Russell Creek's natural channel and reducing sedimentation of the community water supply.

FRBC Region/MELP Region/MOF Region
Kootenay-Boundary/Kootenay/Nelson

Author
Terry Anderson

Proponent/Implementing Partners
Crestbrook Forest Industries Ltd.

Watershed/Stream
Goat River/Russell Creek

Location
Russell Creek is a second order tributary that flows north into Kitchner Creek. Kitchner Creek in turn is a tributary of the Goat River. The mouth of Russell Creek is located approximately 10 km northeast of Creston.

Introduction
Russell Creek is the water supply for Kitchner, BC. It has a drainage area of 24 km^2, a step-pool (boulder/cobble) morphology for most of its length and is defined as a community watershed. The drainage has a "high-grading" logging history dating back to the 1950s with additional clear cut harvesting and road building continuing into the 1990s. The creek channel was destabilized by a flood which occurred in the drainage in the spring of 1997. The channel became severely aggraded causing avulsions down an old forest road in several locations. These avulsions were assessed to be significant and chronic sediment sources.

Assessments and Prescriptions
Russell Creek is a small community watershed that has seen road, hillslope and channel assessments followed by prescriptions and works.

Rehabilitation Work
Stream channel rehabilitation works were undertaken at six sites in conjunction with road deactivation works. The instream works generally consisted of using aggraded streambed material, large woody debris and snags felled for safety reasons to construct berms to cut off the avulsion channels down the old forest road. This action reduced the amount of sediment introduced to the stream from further erosion of the forest road. It also prevented the undercutting of the valley wall that would eventually trigger landslides into Russell Creek and further degradation of the community water supply.

Cost Summary

Labour, Planning and Supervision	$3,511
Machinery and Materials	5,700
Total Cost	$9,211

Outputs
1.5 km of stream was restored.

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INLET CREEK INSTREAM RESTORATION

Objectives
The purpose of this project was to complete a variety of stream and channel restoration techniques, including repairs and maintenance measures for works completed in 1998. This will restore critical fish habitat features for a regionally significant rainbow trout population.

FRBC Region/MELP Region/MOF Region
Kootenay–Boundary/Kootenay/Nelson

Author
Sue Crowley

Proponent/Implementing Partners
Crestbrook Forest Industries Ltd. in partnership with the BC Ministry of Environment, Lands and Parks (MELP).

Watershed/Stream
Inlet Creek

Location
Inlet Creek originates in the Rocky Mountains in southeastern BC and flows to its confluence with Whiteswan Lake, with the lower two reaches within Whiteswan Lake Provincial Park. The project area is located approximately 34 km southeast of Canal Flats, BC.

Introduction
Inlet Creek is a third–order stream with a mainstem length of approximately 10 km, and a total drainage basin area of ~3056 ha. The mainstem has eight identified reaches up to 3300 m in length. The lower reaches are located in the Dry Cool Montane Spruce Subzone (MSdk) at an elevation of 1150 m. The channel slope is constant at 1 to 3% over the project area, with stream bankfull widths from 4.5 to 5.5 m and bankfull depth ranging from 0.3 to 0.8 m. Approximately 61% of the operable forest area of the watershed has been removed through harvesting operations.

Inlet Creek is considered a regionally significant fish stream by MELP due to its excellent rearing potential and valuable spawning habitat for rainbow trout resident to Whiteswan Lake. Spring spawning rainbow trout primarily utilize the lower reaches of the mainstem channel, where restoration efforts are focused.

Assessments and Prescriptions
Fish Inventory data documented exclusive rainbow trout presence within Inlet Creek. Overview and Level 1 Fish Habitat Assessment Procedures (FHAP) were conducted in 1997, leading to restoration concepts for six high priority sites in reaches 1 and 2. A Level 2 FHAP detailed design and prescribed restoration works were completed in 1998.

Past Rehabilitation Work
Site works completed in 1998 were to address specific habitat requirements and limitations for the rainbow trout, including lack of streambank LWD and vegetation, scarcity of pools, fish passage obstructions, sediment and erosion concerns, and aggraded channel conditions. Low site impact methodology was prescribed due to the fisheries importance of Inlet Creek, and its location in the Whiteswan Provincial Park with an associated high public exposure.

The 1998 works rehabilitated approximately 1000 m^2 of stream channel, incorporating 10 structures.

Rehabilitation Work
Work was initiated in late October 1999 to meet an October to April instream fisheries work window requirement. Activities were successfully accomplished during ~10 days on site, prior to heavy snowfall or freezing conditions.

As a result of successful works and expertise demonstrated in 1998, horse logging was again effectively utilized to move and place all large materials, and resulted in low site impact and cost effective methodology (Fig. 4–7).

Specific 1999 site works included:

- Four triangular logjams with additional diagonal logs placed to add complexity, designed to promote pool development at two sites. Logs were cabled in to buried deadman logs at the banks, with further support from ballast rock. Spacing of the structures is consistent with existing cascade–pool morphology adjacent to the sites.

- Log spurs placed to promote pool development were dislodged during high flows in the spring of 1999. Ballast rock was added to upstream log spurs; logs were reinstalled and cabled to buried deadman logs.

Additional rootwad and log material was added to the downstream spur to increase complexity.

A V-log weir constructed in the fall of 1998 was undermined during high flows in the spring of 1999 (Fig. 4–8). The structure was undamaged, but required reinstallation with cabled rock, rootwad and woody debris placement to prevent further undermining, and to allow the channel to aggrade. Additional diagonal logs were placed on the opposing bank facing downstream and keyed in to the centre of the structure to further prevent undermining.

Cost Summary

Total Labour	$ 8,340
Equipment and Materials	9,604
Total Cost	$17,944

Outputs and Production Estimates

Works completed at the 1999 Inlet Creek project sites restored habitat for a total of ~600 m^2, with a 1998–99 cumulative overall improvement to stream channel conditions over 2 km. Observed success as a result of 1998 restoration and monitoring include doubling the average pool depth in the lower reaches of the stream from pre-restoration depths of 0.2 to 0.4 m to a current average pool depth of 0.8 m. Pool frequency has increased to provide holding areas of good quality for spawning adult rainbow trout and valuable overwintering habitat (Fig. 4–9).

For Further Information

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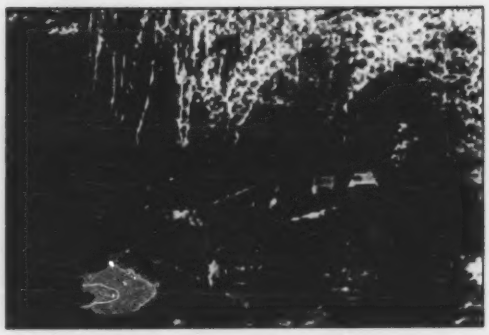

Figure 4–7. Use of horses proved to be cost effective and resulted in low site impact.

Figure 4–8. V-log weir constructed in the fall of 1998 undermined during high flows, spring 1999.

Figure 4–9. Successful results of 1998 restoration: pool depth doubled, and frequency increased.

QUEENS BAY CREEKS— CHANNEL RESTORATION

Objectives
The objectives of this project were to address significant sections of channel disturbance resulting from road-related landslides and road construction in Ross, South Aylmer and North Aylmer Creeks.

FRBC Region/MELP Region/MOF Region
Kootenay-Boundary/Kootenay/Nelson

Authors
Terry Anderson and John Beerbower

Proponent/Implementing Partners
Meadow Creek Cedar Ltd.

Watershed/Streams
Kootenay Lake/Ross Creek, North Aylmer Creek and South Aylmer Creek

Location
Ross Creek, North Aylmer Creek and South Aylmer Creek are located in the Queens Bay area. The unincorporated community of Queens Bay is located 35 km east of Nelson.

Introduction
Ross Creek, North Aylmer Creek and South Aylmer Creek are very small first– and second–order streams. The three streams support 28 domestic and 16 irrigation water licenses.

Large portions of the watersheds were logged in the 1960s and 1970s. An extensive system of roads were built using balanced cut–and–fill (sidecast) construction. Little attention was given to drainage control. Consequently, the streams show significant areas of channel disturbance and instability.

Assessments and Prescriptions
In 1997 Kutenai Nature Investigations Ltd. investigated a landslide and prescribed rehabilitation measures. The Queens Bay Residents Association conducted road and hillslope overview assessments and prescriptions in 1998. Additional assessments and prescriptions followed the next year. In 1998 Martin Carver Consulting and Forterra Consultants Ltd. conducted a channel assessment and sediment source review.

Rehabilitation Work
The instream rehabilitation works were carried out during the summer and fall of 1999 by the Queens Bay Residents Association. All works were completed without the use of large machinery. In all, approximately 500 m of stream was rehabilitated. This included the control of sediment sources, falling of unstable trees, construction of sediment traps, streambank armouring and the manipulation of LWD to reduce channel avulsion potential, control velocity or create steps. In addition, bioengineering was used to rehabilitate a 250 m^2 landslide track.

Cost Summary
Professional Review, Field Trips, Remediation, Follow-up Review, Monitoring and Reporting	
Total Cost	$10,900

Outputs
Approximately 500 m of stream was restored and one landslide rehabilitated.

Production Estimates
The upslope and instream control of sediment will improve the overall water quality of the three domestic watersheds.

Proposed Work
There is additional roadwork planned in the watersheds.

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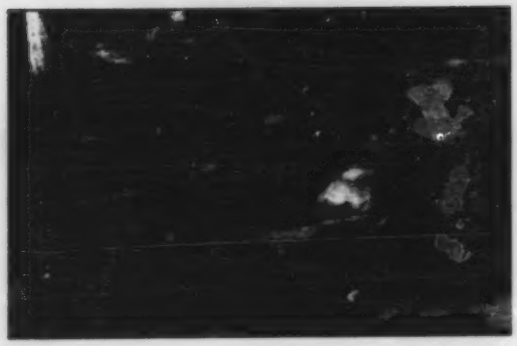

Figure 4–10. The completed sediment trapping pool at Queens Bay; Ross Creek, Site 3.

Figure 4–11. Bermed banks and deepened channel at Ross Creek, Site 3.

Figure 4–12. Deposited sediment was removed, and the channel was deepened at Site 6 on Ross Creek. This photo was taken after works were completed.

JORDAN RIVER BOULDER CLUSTERS

Objectives
The main objective of this project was to stabilize an eroding left streambank within Reach 3 of the Jordan River with two lateral debris catcher structures. Unfortunately high water levels prevented construction of the debris catchers. As a result, boulder clusters were constructed to increase habitat complexity.

FRBC Region/MELP Region/MOF Region
Kootenay–Boundary/Kootenay/Nelson

Author
Cory S. Legebokow

Proponent/Implementing Partners
Ministry of Environment, Lands, and Parks on behalf of Revelstoke Community Forest Corporation of Revelstoke, BC.

Watershed/Stream
Jordan River

Location
Jordan River is located within the Columbia Forest District approximately 3 km northwest of Revelstoke, BC, and flows southeast for approximately 39 km from its glacial headwaters in the Jordan Range of the Monashee Mountains to its confluence with the Columbia River. The watershed has an area of 342 km^2.

The watershed restoration project is located at approximately 9 km adjacent to the Jordan River Mainline FSR.

Introduction
The Jordan River Watershed (Northern Columbia Mountains eco–region; Interior Cedar–Hemlock, Engelmann Spruce–Subalpine, and Alpine Tundra biogeoclimatic zones) was among the first valleys to be harvested within the Revelstoke TSA and has had 15 cutblocks harvested within the riparian management area (DeDominicis and Duane, 1998). Reach 3 of the Jordan River has experienced the highest level of forest development with more than half of the riparian areas harvested to both streambanks.

Reach 1 of the Jordan River is accessible by adfluvial populations of bull trout, kokanee, rainbow trout and mountain whitefish. The remainder of the watershed contains resident populations of bull trout, rainbow trout, westslope cutthroat trout (*Oncorhynchus clarki lewisi*) as well as rainbow–westslope cutthroat hybrids and slimy sculpins (*Cottus cognatus*) (DeDominicis and Beers, 1998). One of the systems main tributaries contains an endemic population of westslope cutthroat trout.

Assessments and Prescriptions
Both a Level 1 Fish Habitat Assessment Procedure (FHAP) and a Riparian Assessment and Prescriptions Procedure (RAPP) were completed for the watershed in 1998.

Rehabilitation Work
Plans to construct two lateral debris catchers were modified due to unusually high water levels during the instream work window. The debris catchers were to be installed on the opposite bank from the access point but water levels and velocities were too high for the crew to work safely. As a result, the boulders collected for structure ballast were used to construct boulder clusters downstream of the clusters installed during 1998 (refer to Zaldokas, Editor 1999). In total, 11 clusters comprised of 4–9 boulders each were constructed. Boulders ranged in size from 1.5 to 3.0 m^3. Cluster configuration was essentially a mid–channel vortex weir. This configuration has created high quality rearing and adult holding habitat (Fig. 4–13).

Cost Summary

Labour	$ 0
Equipment and Materials	4,100
Total Cost	$4,100

Outputs
0.10 km of stream was restored.

Production Estimates
Table 3–4 in Slaney and Zaldokas, Editors (1997) provides an estimate of resident salmonid production for mainstem

habitat complexing. The table suggests a 2.3–fold increase in the total numbers of cutthroat trout and a 2.7–fold increase in total numbers of rainbow trout. Based on results from the West Kettle River, a 5–fold increase in rainbow trout numbers may occur. Koning and Keeley (1997) do not provide biostandards for bull trout.

Snorkel surveys were conducted both prior to and after the 1999 boulder cluster installations. The surveys also covered the work completed in 1998. Poor water clarity and high flows during the pre–project survey (July) limited the numbers of fish observed. However, three of the 18 boulder clusters constructed in 1998 each held one adult cutthroat trout. No fish were observed within the area that received boulder clusters in August 1999. The post–project survey (October) showed adult and sub–adult bull trout associated with two of the 18 boulder clusters constructed during 1998. Each of these two boulder clusters held one bull trout. Additionally, a single bull trout was observed within a lateral scour pool created from one of the three triangular lateral logjams constructed in 1998. No fish were observed within the boulder clusters constructed during 1999. However, anecdotal information from a local fly fisherman suggests that adult bull trout are using the habitat created from these boulder clusters. These bull trout were angled during September when water temperatures were warmer than those during the October survey. It is believed that these fish had moved to deeper water for overwintering purposes prior to the October survey (Runciman, 1999).

Proposed Work

The debris catchers that were to be constructed in 1999 have been deferred until 2000. Additional debris catchers as well as triangular lateral logjams and boulder clusters are planned for sites further upstream within Reach 3 of the Jordan River mainstem.

For Further Information

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Figure 4–13. Boulder cluster configured as a mid–channel reverse vortex weir.

REDDING CREEK—INSTREAM RESTORATION OF TRIBUTARY 780

Objectives
The objectives of this project were to reposition LWD and windfall removal in Reaches 1 and 2. An avulsed channel was relocated back into the original channel in Reach 2 of Tributary 780 of Redding Creek.

FRBC Region/MELP Region/MOF Region
Kootenay–Boundary/Kootenay/Nelson

Author
Herb Tepper

Proponent/Implementing Partners
Crestbrook Forest Industries Ltd., Cranbrook, BC.

Watershed/Stream
St. Mary River/Redding Creek/Trib. 780

Location
Tributary 780 is an unnamed tributary of Redding Creek located at the 32 km marker on the Redding Creek Forest Service Road.

Introduction
Tributary 780 is a second–order tributary of Redding Creek, with a drainage area of 11.6 km^2 and is located approximately 60 km west of Kimberley, BC. Redding Creek drains into the St. Mary's River, which supports a regionally significant recreational fishery. Key species identified in the Redding Creek Watershed include westslope cutthroat trout and bull trout.

The study area extends 690 m from the confluence with Redding Creek, upstream to a waterfall which is a barrier to fish passage. The Redding Creek main FSR crossing of Tributary 780 is located 290 m upstream from the confluence with Redding Creek. The Tributary 780 watershed has been logged and extensive windthrow has resulted in a channel avulsion approximately 200 m upstream of the logging road crossing. The avulsed channel drains back into the original channel at the crossing.

Assessments and Prescriptions
In 1995 and 1996 an Overview and Level 1 Fish Habitat Assessment Procedure (FHAP) was completed for the Redding Creek Watershed by Interior Reforestation Co. Ltd. The FHAP identified the channel avulsion in Reach 2 of Tributary 780 and recommended a Level 2 FHAP be completed.

In 1998, a Level 2 FHAP was completed by AGRA Earth & Environmental on Reach 1 and 2 of Tributary 780. AGRA (1998), recommended 16 prescriptions within Reach 1 and 2. The Reach 1 prescriptions consisted of woody debris reorientation and windfall removal to reduce the risk of channel avulsion. The Reach 2 prescription was to divert the avulsed channel back into the original channel.

Past Rehabilitation Work
In 1997, the Redding Creek mainstem, at the top of Reach 15, was diverted back into the original channel. In 1998, instream structures were built in Reach 16 of Redding Creek (refer to Zaldokas, Editor, 1998; 1999).

Rehabilitation Work
In 1999, all prescriptions proposed in AGRA's Level 2 FHAP were implemented in Reach 1 and 2 of Tributary 780. Fig. 4–14 shows the completed diversion structure in Reach 2. It was built using railway rails as a backbone, windthrow trees, rock and cobble. Fig. 4–15 shows the stream flowing in the original channel in Reach 2.

Cost Summary

Labour	$25,905
Equipment and Materials	24,389
Total Cost	$50,294

Outputs
Approximately 0.7 km (2800 m^2) of instream rehabilitation work was completed.

Proposed Work
During 2000, Tributary 780 will be assessed after spring freshet to determine if minor alterations are required (i.e., repositioning and/or addition of LWD).

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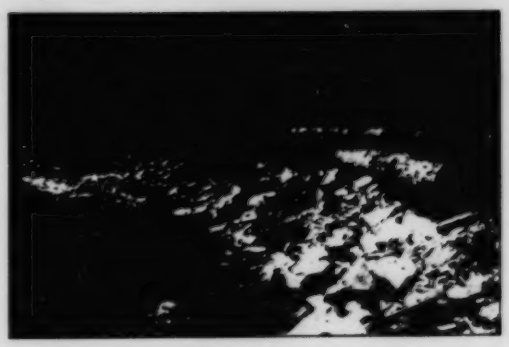

Figure 4–14. The diversion structure in Reach 2 of Tributary 780.

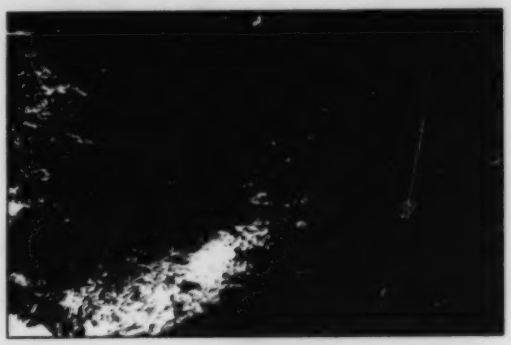

Figure 4–15. The stream flowing back in the original channel in Reach 2 of Tributary 780.

BIGHORN CREEK—INSTREAM RESTORATION OF REACH 2

Objectives
The objectives of this project were to maintain the integrity of the existing channel for sediment transport and lateral stability while providing suitable holding habitat for adult spawners and maintenance of the extensive side channel habitat for juvenile rearing.

FRBC Region/MELP Region/MOF Region
Kootenay–Boundary/Kootenay/Nelson

Author
Herb Tepper

Proponent/Implementing Partners
Crestbrook Forest Industries Ltd., Cranbrook, BC.

Watershed/Stream
Wigwam River/Bighorn Creek

Location
Bighorn Creek is located in the southeast corner of British Columbia in the MacDonald Ranges of the Rocky Mountains, approximately 35 km south of Fernie. Reach 2 of Bighorn Creek is located at the 47 km mark on the Ram Creek Forest Service Road in the Cranbrook Forest District.

Introduction
Bighorn Creek is a tributary to the Wigwam River that flows into the Elk River. Bighorn Creek is a fourth–order stream with a mainstem length of approximately 25 km and a drainage area of approximately 139 km^2. The watershed has an extensive history of disturbances, which include significant wildfires in the 1930s, bug infestations and subsequent large scale clear–cut logging in the headwaters. Three species of sportfish including westslope cutthroat trout, bull trout, and Rocky Mountain whitefish (*Prosopium williamsoni*) have been identified in the watershed. However, recent studies in the watershed only indicate the capture of westslope cutthroat trout and bull trout. As is the case in many interior watersheds, the Bighorn Creek Watershed lacks historical data on fish distribution and population size, thus direct evidence of harvesting impacts in this watershed is not available.

Assessments and Prescriptions
In 1997, an Integrated Watershed Assessment Project (IWAP) was completed by Klohn–Crippen. The IWAP included a Channel Conditions and Prescriptions Assessment (CCPA), a Riparian Assessment and Prescription Procedure (RAPP) and a Level 1 Fish Habitat Assessment Procedure (FHAP). The IWAP indicated homogenization of available fish habitat, due most likely to increase bedload, changes in the hydrologic regime and removal of important LWD sources have constrained fish production in the watershed.

In 1998, a Level 2 FHAP was completed by Westslope Fisheries (Cope, 1998), recommending 18 prescriptions within Reach 2. Pool habitat and in particular, deep holding and cover habitat were identified as a limiting factor. Eight log–rootwad–boulder structures designed to scour pools and provide cover were prescribed to attain pool targets. Lateral stream channel instability was identified as a result of aggradation. Six debris catcher complexes were prescribed to maintain lateral stability and protect side channel and groundwater channels. These structures would also provide scour and cover habitat. Four elevated gravel bars, totalling 310 lineal metres, were prescribed with willow fascine, willow staking and buried large woody debris spurs to stabilize bars and accelerate the re–vegetation process.

Past Rehabilitation Work
In 1998, a rotational clay slump was rehabilitated at the top of Reach 1 in Bighorn Creek (refer to Zaldokas, Editor, 1999).

Rehabilitation Work
In 1999, due to a reduced budget, 11 of the 18 prescribed structures were built in Reach 2. The primary objective of the structures built in 1999 was to rehabilitate channel stability. The remaining structures which will focus on rehabilitating deep holding and cover habitat will be built in 2000.

Five debris catchers were constructed on three outside bends to maintain lateral stability and/or protect side–channels (Fig. 4–16).

Three elevated gravel bars were stabilized with LWD at their upstream ends (Fig. 4–17), buried large woody

debris spurs and willow fascines and stakes planted behind the spurs.

To protect a groundwater channel, 25 m of streambank was rehabilitated with single log deflectors and rootwads.

To rehabilitate deep holding and cover habitat one triangular logjam and one lateral logjam were constructed.

Cost Summary

Planning, Management, Supervision and Reporting	$15,600
Labour	10,400
Equipment and Materials	26,550
Total Cost	$52,550

Outputs

Approximately 0.8 km (8000 m²) of instream work was completed.

Production Estimates

It is estimated that the five debris catchers and the logjams built in 1999 and the triangular logjams which will be built in 2000 will result in a 2.3–fold increase in cutthroat trout numbers within the treatment area based on Koning and Keeley (1997).

Proposed Work

During 2000, the remaining structures proposed for Reach 2 will be built. Also in 2000, instream structures will be built in Reach 1 of Bighorn Creek.

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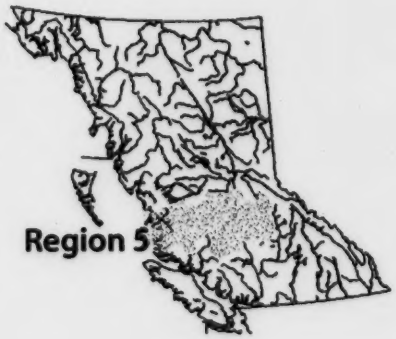
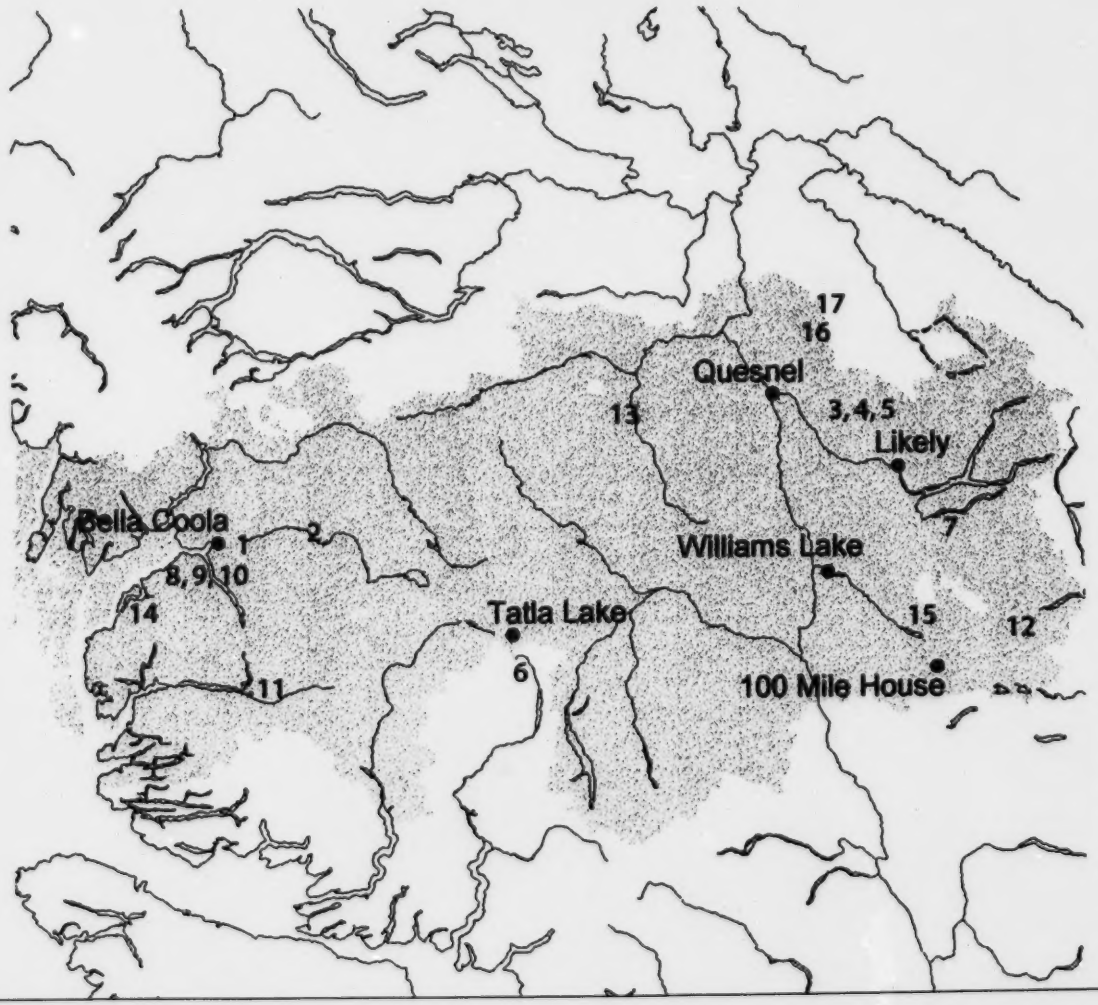
Figure 4–16. Downstream view of lateral debris catchers.

Figure 4–17. Upstream view of a bar stabilizing LWD structure at the upstream end of a bar.

Cariboo Region

Region 5. Cariboo





WRP Projects

1	Bella Coola Valley
2	Talchako River
3	Fontaine Creek
4	Font Creek
5	Horan Creek
6	Homathko/Mosley Rivers
7	Horsefly River
8	Kwatna River
9	Slousiska Creek
10	Motomaster Creek
11	Machmell River
12	Jim Creek
13	Clisbako River
14	Nootum River
15	Timothy Creek
16	Crescent Creek
17	Rebman Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 5, Cariboo.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Cariboo	Bella Coola River	Bella Coola Valley Instream Restoration	9	5805455	651723	910-290700	00455BELA
2		Bella Coola River	Talchako River Groundwater Channels	9	5806891	697596	910-290700-99800	00000BELA
3		Cottonwood River	Fontaine Creek Instream Restoration	10	5864291	580553	100-481100-72900-47300	00000COTR
4		Cottonwood River	Font Creek Instream Restoration	10	5870535	584749	100-481100-72900-47300-7280	00000COTR
5		Cottonwood River	Horan Creek Instream Restoration	10	5868492	583198	100-481100-72900-47300-5030	00000COTR
6		Homathko River	Homathko/Moseley Rivers Instream and Riparian Restoration	10	5643334	369701	900-406900	00000HOMA
7		Horsefly River	Horsefly River Groundwater Channel and Riparian Restoration	10	5814071	609476	160-635400	00000HORS
8		Kwatna River	Kwatna River Instream Restoration	9	5774308	611315	910-246500	00000NEIL
9		Kwatna River	Slousiska Creek Fish Access	9	5770132	618831	910-246500-28400	00000NEIL
10		Kwatna River	Motomaster Creek Groundwater Channel	9			910-246500	00000NEIL
11		Machmell/Sheemahant Rivers	Machmell River Fish Access Improvement	9	5725251	659211	910-128800-60200	000000WIK
12		Mahood River	Jim Creek Weir Construction	10	5733683	663059	129-360400-23900-98400-4800	01824MAHD
13		Nazko River	Clisbako River Instream Restoration	10	5851437	463449	170-324300-38400	00000NAZR
14		Nootum River	Nootum River Instream and Riparian Restoration	9	5756150	590854	910-225900	00000NEIL
15		San Jose River	Timothy Creek Weir Construction	10	5746191	616350	100-385000-98600-98900-5160-9760	00000SAJR
16		Willow River	Crescent Creek Culvert Replacement	10	5903827	573387	100-596500-78400-00700	00000WILL
17		Willow River	Rebman Creek Instream Restoration	10	5914623	564053	100-596500-64100	00000WILL

BELLA COOLA VALLEY FISH HABITAT RESTORATION

Objectives
The objective of this project is to diversify instream hydraulics in selected reaches of tributaries of the Bella Coola River. This can be accomplished by increasing the amount of stable riffle/pool habitat, improving access, and the amount of cover.

FRBC Region/MELP Region/MOF Region
Pacific/Cariboo/Vancouver

Author
Dan DiFiore

Proponent/Implementing Partners
Central Coast Regional District.

Watershed/Stream
Bella Coola River/Dump, Fish, G Hall, Molly Walker, Snootli, Tuck Creeks

Location
These tributaries are located in the lower Bella Coola Valley from 6 km east of the estuary to 37 km east of the estuary.

Introduction
The Lower Bella Coola River Watershed drains a relatively narrow, steep–sided valley. All tributaries included in this project flow at low gradients within the floodplain and through developed lands. Fish values are very high for all salmonid species for both spawning and rearing.

Assessments and Prescriptions
All project streams are part of the Bella Coola Watershed Restoration Project; 1999 was the third year of the program. Initial Level 1 fish habitat assessment was conducted in 1995 by Summit Environmental with more site–specific assessments and prescriptions conducted for individual stream reaches by Ministry of Environment personnel, Fisheries and Oceans Canada, Bioforest Consulting and MidCoast Aquatics. Common factors limiting fish production were primarily found to be channelization, lack of habitat diversity and cover, and restricted access. Poor habitat conditions are mostly caused by human development including logging, cattle grazing, roads and settlement encroachment.

Rehabilitation Work
The restoration of project streams (George Hall, Snootli, and Molly Walker Creeks) occurred largely within lower reaches near or adjacent to their confluence with the Bella Coola River.

Riffles were constructed at a frequency of approximately six times the average bankfull width. The riffle structures consisted of logs that span the bankfull width of the stream and are placed 30 degrees from perpendicular to the flow in an alternating sequence from the left bank to the right bank. The primary materials used to add complexity and provide cover were logs, rootwads, cobble and boulder. The completed project created approximately 50 new or improved riffle/pool and cover habitat sites.

Excavating and complexing of a channel occurred at Tuck Creek, and fencing was installed to address the effects of the cattle in this location. At Fish Creek a beaver dam and derelict bridge were removed and a deep pool excavated and complexed with large woody debris. Maintenance and monitoring was conducted at sites competed in previous years. Previous works had failure rates of less than 10%.

Reconfiguring stream channels into a stepped pattern or more sinuous morphology has created more diverse hydraulic and habitat conditions (Figs. 5–1, 5–2). It also provides more water depth during low flow periods. The constructed riffles will enhance pools, recruit gravel, re–aerate flows, and assist fish passage. The pools will provide holding cover for spawners and rearing habitat for juvenile and resident salmonids.

Cost Summary

Labour	$73,158
Machinery and Materials	48,772
Total Cost	$121,930

Outputs
1.585 km of stream was restored.

Production Estimates

Biostandards for riffle–pool constructions are not well formulated. However, in a small watershed on the Sunshine Coast (Oulette Creek) riffle–pool construction increased pool habitat 4.5–fold. Fish biomass also increased 5.4–fold after restoration (Newbury *et al.*, 1997). Monitoring and evaluation of 1999–2000 works continues.

Proposed Work

The Bella Coola Watershed Restoration Project will continue to work to improve fish habitat throughout the valley. Goals include rebuilding degraded habitat, creating new habitat and protecting existing habitat.

For Further Information

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Figure 5–1. Pre–construction view of Snootli Creek site.

Figure 5–2. Post–construction view of Snootli Creek site.

TALCHAKO RIVER GROUNDWATER CHANNELS

Objectives
The objective of this project is to establish access to existing off-channel habitat along sections of the Talchako and Bella Coola Rivers.

FRBC Region/MELP Region/MOF Region
Pacific/Cariboo/Vancouver

Author
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Proponent/Implementing Partners
International Forest Products, Mid-Coast Division, Hagensborg, BC.

Watershed
Bella Coola River/Talchako River

Location
The Talchako River partially defines Tweedsmuir Provincial Park's southwest boundary. It is located approximately 380 km west of the city of Williams Lake and 60 km east of the community of Bella Coola. Together with the Atnarko River, it forms the Bella Coola River.

Introduction
The Talchako system is limited to salmonid production by low nutrient levels and off-channel rearing habitat. Several off-channel ponds and groundwater channels exist between 72–84 km (Talchako FSR) but are inaccessible to fish.

The access problems are caused in part by past logging activities and increased beaver activity, enhanced by vegetation type change.

Assessments and Prescriptions
In 1999 prescriptions were developed to access more off-channel ponds. Prescriptions were based on information collected in 1996 and 1998 Level 1 assessments. International Forest Products (Neil Oborne) completed the engineering design, for the fish ladders.

Rehabilitation Work
Rehabilitation works focused on several areas of the Talchako and Bella Coola mainstem.

Riparian planting and cattle fencing were undertaken in the McCall Flats area to protect a groundwater channel developed in 1998 (Fig. 5–3). Plastic cones were used to protect juvenile cedar, in an attempt to reduce browse damage by deer.

Access was primarily developed through the construction of low-grade fish ladders around existing beaver impoundments (Fig. 5–4). If suspect, beaver dams were reinforced to make sure water flow was forced through the ladders.

Cost Summary

Labour	$79,100
Machine/Vehicle Expense	14,600
Supplies	4,400
Total Cost	$98,100

Outputs
Groundwater channel construction or improvements occurred at 58, 72, 77 and 78 km of the Talchako FSR. This created access to approximately 13 ha of off-channel habitat, or .550 km.

Proposed Work
During 2000 the following works are proposed:
- monitoring and development of old and new channels along the Bella Coola and Talchako mainstems.

Project monitoring in 2000 will include:
- estimating juvenile salmonid use in the groundwater channels
- evaluating the growth of cedar protected with plastic cones.

For Further Information

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Figure 5–3. McCall Flats groundwater channel. Protective cones were placed over planted cedar to reduce grazing damage by deer and free–range cattle.

Figure 5–4. A series of fry accessible ladders were constructed around old, non–active, beaver impoundments, to access groundwater rearing habitat in the glacial–fed Talchako River system.

FONTAINE CREEK INSTREAM RESTORATION

Objectives
Project objectives were to restore natural thalweg function, stabilize streambanks and increase stream cover through restoration of LWD to selected reaches of Fontaine, Font and Horan Creeks. Methods included LWD, rootwad and boulder cluster placement.

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
G3 Consulting

Proponent/Implementing Partners
West Fraser Mills Ltd. (WFM), Quesnel Division.

Watershed
Cottonwood River/Fontaine, Font and Horan Creeks

Location
Project sites were located on the mainstem of Fontaine Creek and tributary streams of the Fontaine Creek sub–basin, in the upper regions of the Cottonwood River Watershed. Fontaine Creek subsequently flowed into Reddish Creek, then into the Swift River, which flowed into the Cottonwood River. The project area was located approximately 27 km south of Hwy 26, approximately 40 km east of Quesnel. Site access was gained from the 1300 Road between Quesnel and Wells. Five sites were restored on the three subject streams.

Introduction
Anadromous fish do not migrate into the project area. Resident rainbow trout were the target species for the works. The Fontaine Creek drainage has been extensively logged in the past with sections of each study site being adjacent to a logging road or harvested area. The subject streams were first– to third–order with 1.5–5.5 m bankfull width and 1–3.5% gradient at restoration sites.

Assessments and Prescriptions
In 1998, G3 conducted a Level 2 FAHP at the five sites specified by MELP and WFM as requiring fish habitat restoration. LWD abundance and distribution was limited at sites, limiting primary pool distribution and size and fish habitat cover. Bank instability was noted at three sites, and 150 m of channelization had occurred at another site.

Past Rehabilitation Work
Weirs, riffles, and a bridge improved fish access at culverts on five Cottonwood River tributaries during 1998.

Rehabilitation Work
Manual labour and minimal excavator and ATV support was used to place wood, rootwads and boulders at select sites.

LWD structures were keyed into both streambanks at an approximate angle of 30° perpendicular to streamflow. LWD revetments were anchored with boulders secured with epoxy and cables to the structure.

- Site A Fontaine Creek: This site had bank failure associated with an abandoned bridge crossing of Fontaine Creek (Fig. 5–5). A LWD revetment was installed to stabilize approximately 55 m^2 of streambank.
- Site B Font Creek: This site was located immediately upstream of its confluence with Fontaine Creek. Six LWD structures were installed with hand tools, generating approximately 12 m^2 of pool habitat.
- Site C Horan Creek: This site was located in a cutblock that had been logged directly to the streambanks. Bankfull width was approximately 2.5 m. LWD was present in limited abundance and distribution. Further LWD was unlikely given lack of riparian vegetation. Nineteen structures and two LWD revetments were installed, restoring approximately 29 m^2 of pool habitat and stabilizing a further 40 m^2 of streambank.
- Site D Horan Creek: Site D was located approximately 400 m downstream of site C. This section had more conifer trees remaining in the riparian area than site C. Bankfull width was approximately 3.0 m. Seven pieces of LWD were installed in the stream channel using hand tools, restoring approximately 15.5 m^2 of pool habitat.
- Site E Fontaine Creek: Approximately 150 m of Site E had been channelized during past mining. Bankfull width was 5.5 m with dense deciduous tree and shrub stream cover. No LWD was present in the section. Four LWD scour logs were placed to create approximately 30.5 m^2 of pool habitat (Fig. 5–6). A rootwad and 18 boulder clusters were placed to provide additional habitat cover in pools and riffles. A Samsung tracked excavator was used for LWD and boulder cluster placement.

Cost Summary

Fontaine Creek	$14,639
Font Creek	6,274
Horan Creek	20,913
Total Cost	$41,826

Outputs

The total length of restored habitat was 1110 m. Within this area 36 LWD, 19 boulder clusters and 3 LWD revetments were installed. Approximately 87 m^2 pool habitat was created, and 55 m of streambank were stabilized.

Production Estimates

Unknown

Proposed Work

Additional stream works and maintenance.

For Further Information

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Figure 5–5. Fontaine Creek Site E: Upstream view of channelized stream section prior to restoration.

Figure 5–6. Fontaine Creek Site E: Upstream view of LWD scour log and boulder clusters placed to restore pool habitat.

HOMATHKO/MOSLEY RIVERS INSTREAM AND RIPARIAN RESTORATION

Objectives
The objectives for this project were to stabilize streambanks and increase riparian vegetation and stream cover of selected reaches of the Homathko River. Bioengineering of streambanks, riparian vegetation planting, and placement of LWD/rootwad revetments were the methods that were used.

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
G3 Consulting Ltd.

Proponent/Implementing Partners
Tatlayoko Woodlot Association.

Watershed/Stream
Homathko River/Homathko and Mosley Rivers

Location
Project sites were located on private property adjacent to the Tatlayoko Lake Road between Hwy. 20 and Tatlayoko Lake. FHAP Overview and Level 1 Reports refer to this section as Reaches 1–11.

Introduction
The Homathko River Watershed is a fifth–order drainage whose waters flow southwestward from the Chilcotin Plateau into Bute Inlet. The study area included reaches upstream of Tatlayoko Lake only. Anadromous fish do not migrate into the study area. Resident target fish species included rainbow and bull trout.

The drainage area of the study area comprises approximately 950 ha. A large percentage of the Homathko River valley is private property and moderately to heavily developed for agriculture.

Assessments and Prescriptions
In 1997 and 1998, G3 conducted Overview and Level 1 FHAP and RAP studies within the watershed boundaries, and identified specific reaches for detailed Level 2 FHAP and RAP surveys, that were subsequently completed.

Portions of the riverbank were cleared of natural riparian vegetation. Along these areas, deciduous shrubs and trees, with limited coniferous forest dominated remaining riparian vegetation. Throughout undisturbed sections of the valley floor, Douglas fir, hybrid spruce and lodgepole pine (*Pinus contorta*) dominated riparian areas.

The Homathko River channel exhibited relatively high levels of bank instability where it passed through agricultural fields. LWD was noted to be low in abundance and poor in distribution, contributing to low levels of instream fish habitat cover. The low gradient (~0.5%) stream channel was aggrading, with fine sediment deposition noted throughout. It was noted that there was infilling of holding pools and blanketing of suitable spawning gravel with fine sediment. This might be attributed to extensive bank erosion and lack of localized hydrological scour normally associated with LWD placement.

Past Rehabilitation Work
None.

Rehabilitation Work
An Environmental Youth Team (E–Team) provided labour support for bioengineering, riparian planting and structure placement. A Kubota KX91–2 rubber track excavator was used for rootwad and revetment placement. Reaches 4, 5 and 11 were selected for restoration activities.

- Reach 4: Restoration included placing LWD/rootwad revetments at 10 sites (Fig. 5–7), including bioengineering at nine sites, and two areas for riparian tree planting. In total 19 rootwads and 18 tree revetments (eight with rootwads) were placed in the river channel; approximately 170 m of streambank was revegetated with live stakes; seven facines were installed and approximately 1500 m^2 planted with 700 tree stems.
- Reach 5: Similar prescriptions to those of Reach 4 were applied to Reach 5. This resulted in placement of seven rootwads, 12 tree revetments, 110 m of bank live staking, placement of 12 facines and approximately 35 m of brush layering. In addition, a riparian area of ~1200 m^2 was planted with trees.
- Reach 11: Work done in this reach included hand placement of LWD and rootwad structures along a 1000 m stream section that originally only had one piece of functioning LWD. Approximately 1200 m^2 of riparian area were planted with trees, with ~200 m

of streambank receiving live staking and fascine placement.

Cost Summary

Labour	$28,100
Equipment	12,000
Materials	6,500
Total Cost	$46,600

Outputs

54 rootwads (~120 m^2 instream cover)
30 revetments (~450 m^2 instream cover)
2,100 trees planted in riparian areas
480 m of streambank revegetated and stabilized through bioengineering.

Production Estimates

Approximately 570 m^2 of instream cover (representing an area of approximately 23% of available area) were restored (reaches 4, 5, and 11). It is difficult to apply biostandards to restoration of cover.

Proposed Work

Work has been prescribed for approximately 13 other sites in Homathko and Mosley River drainages.

For Further Information

Contact
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Figure 5–7. Installation of LWD revetment during late summer high flow, Homathko River.

HORSEFLY RIVER GROUNDWATER CHANNEL AND RIPARIAN RESTORATION

Objectives
Within the Horsefly River Riparian Conservation Area/ Black Creek Ranch the objectives are to develop off–channel habitat for juvenile salmonids, re–establish riparian corridors, and stabilize banks (reduce sedimentation).

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
Mike Ramsay

Proponent/Implementing Partners
Riverside Forest Products, Lignum Forest Products (with technical support from MELP).

Watershed
Horsefly River

Location
The Horsefly River Watershed is located approximately 50 km northeast of Williams Lake.

Introduction
The Horsefly River is one of British Columbia's leading sockeye streams. It is also critical habitat for Quesnel Lake rainbow trout, and chinook and coho salmon. The watershed displays a high level of habitat degradation, particularly affecting overwintering salmonids. Excessive sedimentation and high water temperatures are the two main problems. Both are due, in part, to the lack of riparian cover and poor riparian condition along the river.

Assessments and Prescriptions
The Horsefly River Conservation Area was subject to a riparian assessment (R.L. Case and Associates). The Ministry of Environment, Lands, and Parks Watershed Restoration staff developed prescriptions.

Rehabilitation Work
The focus of the 1999 restoration work was initiated in an attempt to alleviate the two identified limiting factors on rearing juvenile salmonids: high summer water temperatures and high sedimentation.

In August 1999 a groundwater channel (approximately 400 m long, 5 m wide, and 2–3 m deep) was established on the lower Horsefly River Riparian Conservation Area (Fig. 5–8). The groundwater source was 9°C, producing up to 50 litres per minute. The new channel will provide mid–summer refuge for all salmonids with temperatures lower than the in–river channel. Warmer than in–river channel temperatures should provide exceptional rearing in mid–winter.

Throughout the spring, summer and fall riparian planting was conducted. Willow staking occurred on both mechanically "pulled back" and existing banks (Fig. 5–9). Riparian species such as spruce, cottonwood, willow and red osier dogwood were also planted.

Cost Summary

Labour	$49,000
Bank Stabilization	4,400
Channel Excavation	42,100
Total Cost	$95,500

Monitoring
Project monitoring in 1999 will include:
- quantifying varying levels of willow growth on mechanically "pulled back" versus naturally eroded banks;
- estimating juvenile salmonid use in the groundwater channel;
- evaluating the growth of riparian species.

Proposed Work
In 2000 the following works are proposed:
- extending the groundwater channel for another 300 m;
- further riparian planting with several more species; experimentation with scarification;
- stabilizing the banks with rootwads and stems.

For Further Information

Contact

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Figure 5–8. Beginning the excavation of the groundwater channel along a depression in the floodplain, Horsefly River.

Figure 5–9. Pull back of vertical banks along the Horsefly River. Note the sods were staked to new slope, willow stakes inserted, horizontal facine at bottom of slope, and initial groundcover with fall rye.

KWATNA RIVER GROUNDWATER CHANNELS

Objectives
The purpose of this project was to provide access to existing, and constructed off-channel habitat along sections of the Kwatna River and tributaries.

FRBC Region/MELP Region/MOF Region
Pacific/Cariboo/Vancouver

Author
Mike Ramsay

Proponent/Implementing Partners
International Forest Products, Mid-Coast Division, Hagensborg, BC.

Watershed/Stream
Kwatna River/Kwatna River, Motomaster Creek, Slousiska Creek

Location
The Kwatna River is located within the Mid-Coast Forest District of the MELP Cariboo Region, approximately 55 km west of the community of Bella Coola.

Introduction
The Kwatna River is a productive coastal river. Coho and pink salmon are the major production species; steelhead, chum and chinook salmon are also present. Extensive logging has occurred throughout the valley. Some past logging practices have degraded fish habitat.

Assessments and Prescriptions
Prescriptions were developed in 1999, primarily to access more off-channel habitat. Prescriptions were based on overview information collected in 1997 (Grizzly Holdings Ltd.) and Level 2 FHAP prescriptions developed in 1998 (LGL Ltd.). International Forest Products (Neil Oborne) completed the design for fish ladders, and LWD placements.

Rehabilitation Work
Rehabilitation works focused on several areas of the Kwatna River and tributaries. In a few select areas of the mainstem LWD was placed to evaluate their function and practicality. These will be assessed in 2000 and more LWD will be placed if last year's work was deemed of value.

In Motomaster Creek a 350 m^2 groundwater channel was constructed (Fig. 5-10). Selected areas of a small natural spring were excavated. Cover components will be considered in upcoming years.

Access to a beaver impoundment was constructed on a tributary to Slousiska Creek. A juvenile ladder system was constructed opening approximately 100 m^2 of off-channel habitat.

Cost Summary

Labour	$22,500
Machine/Aircraft/Vehicle	54,000
Camp Costs/Supplies	14,500
Total Cost	$91,000

Outputs
Construction and access projects have provided 450 m^2 of rearing habitat.

The estimated length was .05 km.

Proposed Work
In 2000 the following works are proposed:
- monitoring and development of old and new channels along the Kwatna and its tributaries.

Project monitoring in 2000 will include:
- estimating juvenile salmonid use in the off-channel habitat constructed in 1998 and 1999;
- evaluation of the mainstream LWD placements.

For Further Information

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Figure 5–10. Motomaster Creek groundwater channel and complexing.

MACHMELL RIVER FISH ACCESS IMPROVEMENT

Objectives
The objectives for the Machmell River project were to improve access of migratory fish to areas with superior habitat, to increase habitat complexity, and to prevent further habitat degradation.

FRBC Region/MELP Region/MOF Region
Pacific/Cariboo/Vancouver

Author
Ivan Stefanov, SRM–Levelton

Proponent/Implementing Partners
Western Forest Products Limited.

Watershed/Stream
Machmell and Sheemahant Rivers

Location
Owikeno Lake is located at the tip of Rivers Inlet, approximately 80 km south of Bella Coola. The waterbody is at the base of the western slope of the Coast Mountains. Machmell River enters Owikeno Lake just west of the First Narrows, near Machmell Logging Camp. Sheemahant River enters the lake near the Second Narrows, at the Sheemahant Logging Camp.

Introduction
The watersheds of Machmell and Sheemahant Rivers have been subject to timber harvesting. At several locations old log box type culverts have failed, and/or have been partially blocked by beaver activity and debris, thus impeding or preventing fish migration, including anadromous salmonids, to areas with high value fish habitat.

Assessments and Prescriptions
Overview and Level 1 FHAP assessments were completed on the Machmell, Neechanz, and Sheemahant watersheds by Judy Hillaby Consulting and Madrone Consulting in 1998. Level 2 FHAP and site specific prescription concerning the 15 Moderate to High rated restoration sites were prepared by AGRA Earth and Environmental in 1999. The latter company identified, and developed prescriptions for, six sites in the Sheemahant and Machmell watersheds. Three sites were addressed during the 1999 restoration activities. Restoration activities were conducted following AGRA's prescriptions.

Past Rehabilitation Work
None.

Rehabilitation Work
The following rehabilitation activities were performed between August 15 and 27, 1999:

- Site MM07, replacement of a culvert structure and construction of two rock weirs to maintain adequate water depth in the culvert and the pool upstream of the road crossing (Fig. 5–11). An existing upstream pool was complexed with LWD and enlarged (Fig. 5–12). A sediment control structure was built at the outfall of the road ditch. Bank disturbance from implementation was addressed with seeding.
- Site SM14, replacement of wooden box culvert.
- Site SM26A, replacement of wooden box culvert, erosion scarp was excavated to approximately 6% and armoured, banks along upstream pool were armoured with riprap, mixed seed was spread on the exposed portions of the banks to encourage revegetation and limit runoff erosion.
- Site SM26B, box culvert was replaced, and streambanks around the culvert were armoured.

Cost Summary
Total Cost	$65,000

Outputs
- access to 380 linear metres of habitat was improved;
- 120 m^2 of juvenile salmonid summer rearing habitat were created.

Production Estimates
There is no baseline production data or estimates for the restored sites. However, Koning and Keeley (1997) reported 1.8– and 1.5–fold increases in fish density for 0+ coho and steelhead, respectively at sites subject to restoration activities.

In the instance of site MM07, the combined effect of improved access and ameliorated habitat could lead to a significant increase of the anadromous and resident salmonid populations.

It is assumed that the upgrading of the culvert at site SM14 will aid in maintaining the integrity of approximately 100 m of stream habitat in the stream and approximately 100 m of habitat in the recipient side channel of the Sheemahant River.

Restoration work at Sites 26 A and B will improve access to a large wetland, which has superior coho rearing habitat.

Proposed Work

Three more restoration sites, SM04, SM08 and Machmell lower dyke should be evaluated for future work.

For Further Information

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Figure 5–11. Site MM 07—view of culvert, retaining weirs and the resulting pools.

Figure 5–12. Site MM07—view of excavated pool with LWD positioned at approximately 40° angle.

CLISBAKO RIVER INSTREAM RESTORATION

Objectives
The objectives of this project were to create a more complex habitat for salmonids through the introduction of large woody debris (LWD) structures and the construction or improvement of rock riffles.

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
Colin Lake

Proponent/Implementing Partners
Slocan Forest Products, Quesnel.

Watershed/Stream
Nazko River/Clisbako River

Location
The Clisbako River is located approximately 125 km west of Quesnel. Access via Nazko Highway, Honolulu FSR and 7000Z Road.

Introduction
The Clisbako River is a tributary to the upper Nazko River, in the Chilcotin Plateau. The total area of the Clisbako River Watershed is 816 km^2. As a result of logging in the upper watershed, LWD recruitment is low and the resulting lack of channel complexity may limit available holding and rearing habitat. It was also likely that compacted gravel precludes spawning success. The target species are resident rainbow trout and anadromous chinook.

Assessments and Prescriptions
The Clisbako River was included in a watershed–wide IWAP Assessment of the Nazko River completed in 1996. A Level 1 FHAP was then conducted, identifying a lack of channel complexity as a limiting factor to fish production. Large woody debris structures and pool construction were identified as possible remedial techniques. In 1998 LGL Ltd. completed a Level 2 FHAP, "Clisbako Watershed Restoration Program–Fish Habitat Prescriptions". The report identifies the lower reach of the Clisbako as having 52% glide, 35% riffle and 12% pool habitat. Compaction and siltation were found to be high, while LWD density was low. This report also outlines structure design and location of those structures.

Past Rehabilitation Work
None.

Rehabilitation Work
Implementation of the restoration plan was carried out by Erosion Control Incorporated (ECI). As outlined by the restoration prescriptions, rehabilitation works was conducted in Reach 1 of the Clisbako River.

A total of 13 LWD structures were built, using one of three designs (Fig. 5–13). Variations in design reflected the structure's location and function in the stream. For example, one design was used on areas where bank erosion was a concern, one structure was used on outside bends, and another was used on the relatively straight sections of the river to increase habitat complexity. Logs used in these structures were anchored in a variety of ways including: boulder ballast pairs, deadman anchors, and cabling to trees or stumps. Ease of installation and effectiveness of each method dictated which type of anchor was used on each site.

Most LWD structures also had a riffle enhancement associated with them (7 sites). Three sites were riffle enhancements alone, without an associated LWD structure. Riffles were constructed using boulders varying from 0.4 to 0.8 m diameter (Fig. 5–14). Generally, the larger boulders were used to construct the crest of the riffle with the smaller material making up the downstream portion. If pool excavation was prescribed, natural substrate excavated during construction was also used.

Upon completion of work, any access trails along or to the river were deactivated. This was done for aesthetic reasons and to prevent access by free–range cattle.

Cost Summary

Labour	$42,800
Equipment	16,165
Materials	6,235
Total Cost	$65,200

Outputs

Approximately 960 m of channel was rehabilitated with 20 separate structures.

Production Estimates

After similar projects (habitat complexing) anadromous adults experienced a 9.3–fold increase in numbers. Resident rainbow have also shown modest increases in numbers following this type of habitat enhancement, with a 1.3–fold increase in >15 cm fish (Koning and Keeley, 1997).

Proposed Work

There is no further work proposed for the Clisbako, aside from routine effectiveness monitoring.

For Further Information

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Figure 5–13. Lateral LWD placement on the Clisbako River.

Figure 5–14. Rock riffle construction on the Clisbako River.

NOOTUM RIVER INSTREAM AND RIPARIAN RESTORATION

Objectives
The objective of this project is to improve the instream hydraulics in selected reaches of tributaries of the Nootum River by decreasing the amount of instream small organic debris (SOD) from past logging practices, and removing the threat of further SOD contribution posed by previously girdled alder from riparian areas.

FRBC Region/MELP Region/MOF Region
Pacific/Cariboo/Cariboo

Author
Dan DiFiore, MidCoast Aquatics

Proponent/Implementing Partners
MacMillan–Bloedel/Weyerhaeuser.

Watershed/Stream
Nootum River/25 tributaries

Location
These first order tributaries are located throughout the Nootum Valley from 5 km to 15 km.

Introduction
The Nootum River Watershed drains a relatively narrow, steep–sided valley. All project tributaries flow at low gradients within the floodplain and through areas logged between 1988 and 1994. Fish values are high for all salmonid species for spawning and particularly rearing.

Assessments and Prescriptions
All project streams are part of the Nootum River Watershed Restoration Project. 1999 was the first year of the project. Initial Level 1 fish habitat assessment was conducted in 1998 by MidCoast Aquatics. More site specific Level 2 assessments and prescriptions were also conducted by MidCoast Aquatics in 1999. Impacts to fish habitat include concentrations of small woody debris, aggradation of stream channel from fine sediments, lack of gravels, pools and cover, and girdling of alders within the riparian zone. The rehabilitation of riffle/pool channels will increase rearing/overwintering capacity for juvenile coho throughout and potentially provide coho and trout spawning habitat as well.

Rehabilitation Work
The restoration of project streams occurred largely within lower reaches near or adjacent to their confluence with the Nootum River. Small organic debris (SOD) less than 10 cm diameter *or* 2 m in length was to be removed by hand from the bankfull channel (Fig. 5–15). All material was removed a minimum of 4 m away from the bankfull channel edge. Existing LWD was left in place in the channel to promote scour and provide stability.

Girdled standing alder less than 15 cm in diameter were removed by hand from the riparian zone. All material was removed a minimum distance from the bankfull channel edge equal to or exceeding the height of the tree. Branches of trees greater than 15 cm were cut from the trunk up to a height of 3 m and removed a minimum of 4 m away from the bankfull channel edge.

Improving flows and reconfiguring stream channels into a stepped pattern or more sinuous morphology has created more diverse hydraulic and habitat conditions (Fig. 5–16). It also provides more water depth during low flow periods. The re–established riffles will enhance pools, recruit gravel, re–aerate flows, and assist fish passage. The pools will provide holding cover for spawners and rearing habitat for juvenile and resident salmonids.

Cost Summary

Labour	$23,689
Machinery and materials	52,996
Total Cost	$76,685

Outputs
2.91 km of alder removal
2.17 km SOD removal

Production Estimates
Biostandards for riffle–pool constructions are not well formulated. However, in a small watershed on the Sunshine Coast (Oulette Creek) riffle–pool construction

increased pool habitat 4.5–fold. Fish biomass also increased 5.4–fold after restoration (Newbury *et al.*, 1997). Monitoring and evaluation of 1999–2000 works continues.

Proposed Work

This year's work will involve re–evaluating conditions in the tributaries after winter rains and prescribing activities that will directly improve fish habitat such as the addition of LWD for pool formation and cover as well as the possible excavation of rearing channels.

For Further Information

Contact

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Figure 5–15. Pre–SOD removal view of stream.

Figure 5–16. Post–restoration view of stream.

TIMOTHY CREEK/JIM CREEK WEIRS

Objectives
The objective at these locations was to construct a weir to allow fish passage through existing culverts, thereby increasing upstream habitat.

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
Mike Ramsay

Proponent/Implementing Partners
Ainsworth Forest Products, 100 Mile House, BC.

Watershed
San Jose River/Timothy Creek; Mahood River/ Jim Creek

Location
The San Jose River Watershed is located between Lac La Hache and Williams Lake along Hwy. 97. Timothy Creek is located 10 km northeast of Lac La Hache.

The Mahood River Watershed is located 50 km southeast of 100 Mile House. Jim Creek is located at the south end of (and flows into) Canim Lake.

Introduction
Both Timothy Creek and Unnamed Creek (flowing into Jim Creek) have high densities of rainbow trout. Road building for logging had eliminated access through two major culverts along these roads (the 1600 and 1900 Roads, respectively). Residualized trout were isolated from mainstem populations, and rainbows from downstream lakes were not able to utilize all available spawning and rearing habitat.

Assessments and Prescriptions
Barriers were identified by MELP habitat and fisheries staff.

Rehabilitation Work
Weirs were constructed of large angular rock, cleaned prior to construction. Culvert outflow pools were developed and a small riffle was constructed below the pool.

Cost Summary

Timothy Creek	$10,000
Unnamed Creek	10,000
Total Cost	$20,000

Outputs
In the case of the Timothy Creek crossing it is estimated access was provided to an additional 28.5 km of stream. On Unnamed Creek (flowing into Jim Creek) it was estimated that 3.2 km of stream was gained.

Proposed Work
In 2000 the following works are proposed:
- Identifying any other barriers on either system.

Project monitoring in 2000 will include:
- Estimating new rainbow trout fry saturation levels above and below the barriers.

For Further Information
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CRESCENT CREEK CULVERTS—REMOVING FISH BARRIERS

Objectives
On Crescent Creek the objective is to remove the fish barrier created by the culverts under the 24P Road.

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
Alan Hunter

Proponent/Implementing Partners
West Fraser Mills Ltd., Quesnel.

Watershed
Willow River/Crescent Creek

Location
The fish barrier is located at the point where the 24P Road crosses Crescent Creek. The site is 250 m from the junction of the 24P Road with the 2400 Road at 29 km of the 2400 Road.

Introduction
Two 1525 mm culverts were installed on Crescent Creek in the late 1970s when the road was built. The water velocity inside the culverts and the drop at the outlet prevented upstream movement of immature fish.

Prescription
Ministry of Environment staff identified this problem as a priority for remediation several years ago. Approval to remove the culverts and replace them with a 17 m bridge was given in the summer of 1999. Because of the inability to have design work and fabrication done in time to install the bridge in the July–August fish window, approval was given by MELP and DFO for installation in early October. A sediment fence was installed downstream of the culverts, and a fine-mesh net was installed upstream of the culverts. Electroshocking was done between the barriers, and collected fish were released downstream of the sediment fence.

Past Rehabilitation Work
None.

Rehabilitation Work
Two 1525 mm culverts were removed (Figs. 5–17, 5–18 and 5–19) and replaced with a 17–m prefabricated concrete bridge. The bridge is mounted on steel piles. The stream channel and banks were lined with riprap to prevent scouring and to mimic, as closely as possible, a natural streambed (Fig. 5–20).

Cost Summary

Bridge	$69,200
Installation (contracted)	8,000
Site preparation: (hauling and installing riprap, removing culverts)	18,630
Labour	1,300
Total Cost	$97,130

Outputs
7 km of stream above the bridge is now accessible for migrating fish; tributaries and two lakes are not included in this estimate.

Production Estimates
Unknown

Proposed work
No further work is planned on this tributary.

For Further Information
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Figure 5–17. Diversion into one culvert.

Figure 5–18. Lifting first culvert.

Figure 5–19. Bridge installed, channel completed.

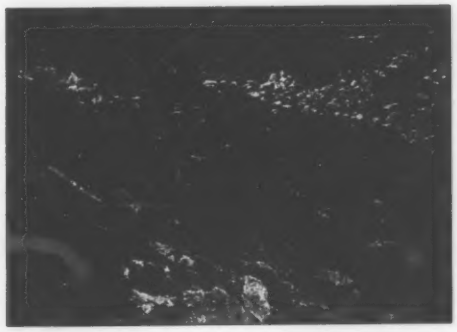

Figure 5–20. Prepared streambed after culvert removed.

REBMAN CREEK POOL AND COVER RESTORATION

Objectives
The objectives of this project were to restore holding and rearing habitats for rainbow trout in Rebman Creek.

FRBC Region/MELP Region/MOF Region
Cariboo–Chilcotin/Cariboo/Cariboo

Author
Dave McEwan

Proponent/Implementing Partners
MELP, Weldwood of Canada Ltd., Quesnel.

Watershed/Stream
Willow River/Rebman Creek

Location
The Rebman Creek work sites are reached by heading from Quesnel to Barkerville on Highway 26 for approximately 50 km. Turn north at the West Fraser 2400, 24P and 900A logging roads. The access to the Reach 2 and Reach 4 rehabilitation sites are approximately 3 and 6 km along the 900 A Road, respectively. Deactivated access roads lead down to the sites.

Introduction
The upper Willow River Watershed is approximately 55 km northeast of Quesnel. Rebman Creek enters the Willow River at the top of Reach 2. The tributary lies near the northern edge of the Quesnel Highland physiographic region and has a total watershed area of 21 km^2.

Rainbow trout are the dominant species in Rebman Creek and are the target of restoration works.

Assessments and Prescriptions
The Willow River Watershed was selected by Ministry of Environment, Lands and Parks, Ministry of Forests and Weldwood of Canada Ltd. for restoration of fish habitat damaged by logging.

A Level 1 Fish Habitat Assessment (FHAP) of selected reaches in the Willow River Watershed was conducted in 1997. Rebman Creek was identified as a heavily impacted system and a high priority for stream restoration. The lower 7 km of the stream has been logged to the streambank and has caused bank erosion, aggradation, formation of mid-channel bars, infilling of pools and loss of cover including LWD.

Level 2 Fish Habitat Restoration Prescriptions were completed by LGL Limited and Northwest Hydraulic Consultants Ltd. in 1999.

Past Rehabilitation Work
Riffles were constructed in Reach 4 in 1998. Three hundred metres of new habitat were created through 83 m of construction.

Rehabilitation Work
The Level 1 FHAP for Reach 2 and Reach 4 rated the percentage of pools and pool frequency as poor. The number of functional pieces of LWD in these reaches for creating pools and providing cover was also considered inadequate in the Level 1 report.

Work was completed at a total of 19 sites over a linear distance of nearly 1 km. For each work site a LWD structure and a riffle were constructed. Pools were excavated upstream of the riffle at the location of the LWD structure. The LWD structures were built to provide cover and scour at the excavated pools (Fig. 5–21). The following two basic designs for the LWD structures were used with a few site specific modifications: 1) A triangular lateral logjam with two 6–8 m logs with rootwads and an additional rootwad piece; and 2) A lateral log jam with five 6–8 m logs with rootwads. The LWD structures were ballasted with boulders brought in to the site. The structures were also anchored to the bank by embedding the top 3–4 m of the logs and attaching rock ballast to the logs in the bank.

A riffle base was constructed by having crews move material by hand. An excavator would then move larger boulders from the pool excavations to the riffle surface. The excavator was used to strategically place large boulders on the crest and face of the riffle to provide stability. A

pool was also excavated downstream of the riffle. A schematic construction drawing of the basic riffle design used in Rebman Creek can be found in Chapter 12, figure 12–12 of WRP Technical Circular No. 9 (Newbury *et al.*, 1997).

A total of 14 sites over 810 m of Reach 2 were completed. The Level 2 prescriptions proposed that the restoration of this section of Reach 2 would provide the greatest benefits to the target species, rainbow trout. Five sites were completed in Reach 4 over 170 m. Three of the riffle constructions in Reach 4 involved adding larger material to riffles that were constructed in 1998.

Cost Summary

Labour	$43,956
Equipment	24,809
Materials	6,235
Total Cost	$75,000

Outputs

Channel reconstruction and installation of restoration works were undertaken on nearly 1 km of stream. As well, approximately 160 person–days of employment was created based on an 8–hour work–day.

Production Estimates

WRP Technical Circular No. 9 indicates that an approximate 2–fold increase in resident rainbow trout numbers can be expected as a result of the instream works (Koning and Keeley, 1997).

Proposed Work

Construction of riffle–pool sequences in Reach 2 downstream of the current year's work should be undertaken in 2000. The next priority would be to reconstruct 460 m of Reach 3.

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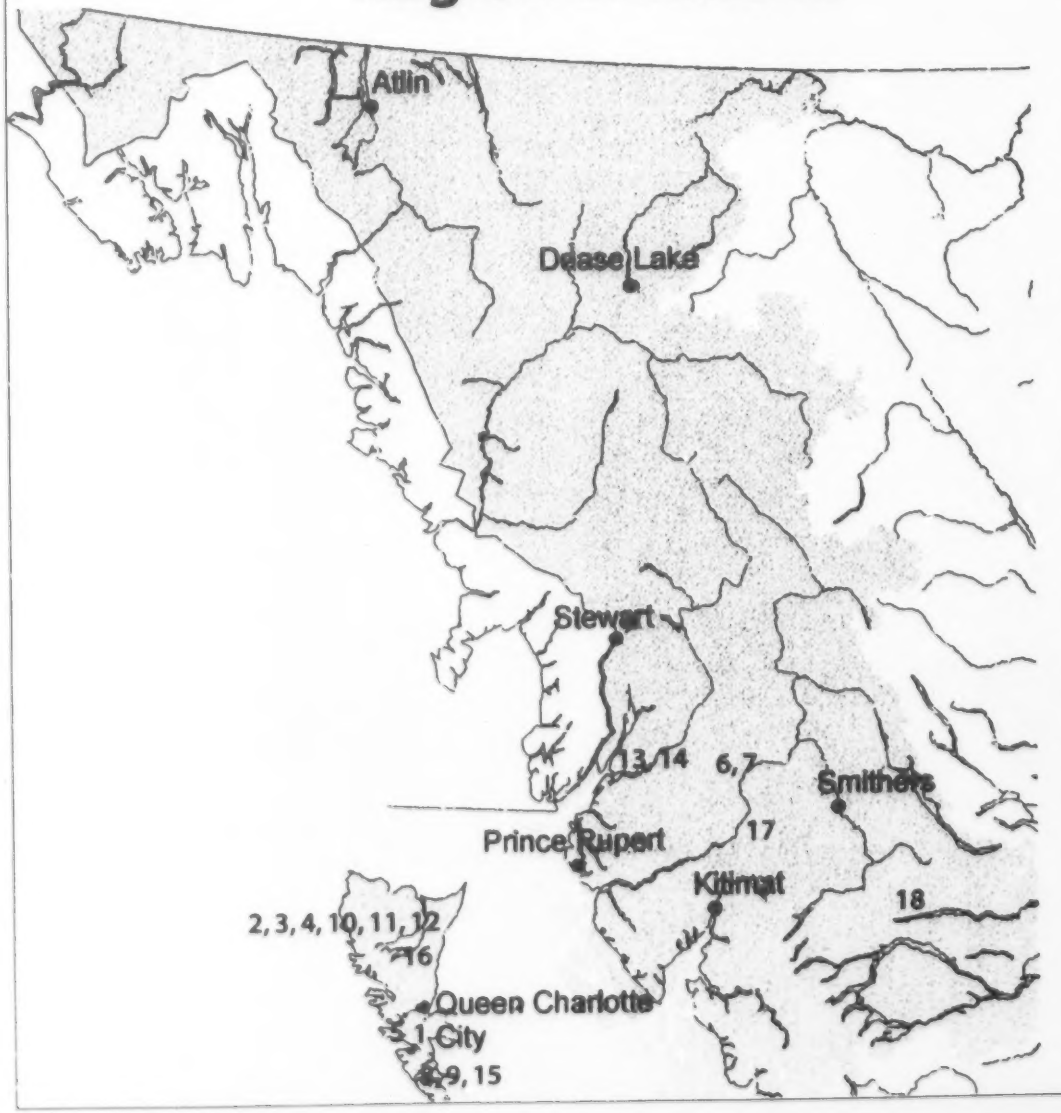
Figure 5–21. On Rebman Creek complexity was added to this pool using LWD structures.

Skeena Region

Region 6. Skeena



WRP Projects

1	Copper Creek
2	15 Km Creek
3, 4	Torney Creek
5	Weeping Willy
6	Clear Creek
7	Glacier Creek
8	Clew Creek
9	Tributary 20 LB
10	Camp Creek
11, 12	Lower Naden River
13	Greenville Creek
14	Ginlulak Creek
15	Thorsen Creek
16	Clay Creek
17	Zymoetz River
18	Fenton Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 6, Skeena.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Skeena	Copper Creek	Copper Creek Instream Restoration	9	5893871	312775	950–010400	00000MORI
2		Davidson Creek	15 Km Creek Slide Bioengineering	8	5980625	651944	940–661700	00000GRAI
3		Davidson Creek	Torney Creek Bar Stabilization	8	5980625	651944	940–661700	00000GRAI
4		Davidson Creek	Torney Creek Pond	8	5981000	652000	940–661700	00000GRAI
5		Deena Creek	Weeping Willy Creek Instream Restoration	8	5891558	690263	950–974300–17200	00000MORI
6		Kitsumkalum River	Clear Creek Side Channel	9	6075418	513248	430–465300	00000KLUM
7		Kitsumkalum River	Glacier Creek Fan Stabilization	9	6057514	517570	430–256600	00000KLUM
8		Mathers Creek	Clew Creek Instream Restoration	9	5877796	313760	955–018000–38300	00000MORI
9		Mathers Creek	Tributary 2.0 LB Instream Restoration	9			955–018000	00000MORI
10		Naden River	Camp Creek Instream Restoration	8	5978588	652175	940–665100	00000GRAI
11		Naden River	Lower Naden Reach 3–4 Instream Restoration	8	5978588	652175	940–665100	00000GRAI
12		Naden River	Lower Naden Reach 4–2 Instream Restoration	8	5978588	652175	940–665100	00000GRAI
13		Nass River	Greenville Creek Instream Restoration	9	6098674	463409	500–076200	00000LNAR
14		Nass River	Ginlulak Creek Instream Restoration	9	6099370	468612	500–090500	00000LNAR
15		Thorsen Creek	Thorsen Creek Off-channel and Instream Restoration	9	5862597	301569	950–105500	00000MORI
16		Yakoun River	Clay Creek Bioengineering	9			940–896100	00000GRAI
17		Zymoetz River	Zymoetz River Culvert Replacement	9	6044733	533524	440	00000ZYMO
18		Morice River	Fenton Creek Fish Access	9	6008368	637417	460–600600–26600	00000MORR

MAINSTEM COPPER RIVER LWD STRUCTURES

Objectives
The objective was to replenish LWD structures in the mainstem river to improve adult holding, juvenile rearing and overwintering habitat for salmonids (primarily coho as well as sockeye, steelhead and cutthroat) in the Copper River Mainstem.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Leandre Vigneault

Proponent/Implementing Partners
JS Jones Ltd.

Watershed/Stream
Copper River

Location
The Copper River is located on Haida Gwaii in the northern portion of Moresby Island. The work site can be reached by driving southeast from Sandspit along the JS Jones logging road (South Bay Mainline past the community of Copper Bay to the 17 mile mark. The two work sites are located within 300 meters of the 17–mile sign.

Introduction
The Copper River drains Skidegate Lake, a large lake located in the northern–central portion of Moresby Island. Both the Skidegate Lake Basin and the Copper River has been extensively logged since 1900. The Copper River and Skidegate Lake support important runs of coho, sockeye and pink salmon as well as steelhead and cutthroat trout. The Copper River mainstem has a stable, well–incised channel; however, the entire riparian zone was logged during the past 60 years and the South Bay Mainline was built within 100 m of the river for most of its length. The LWD structures that are found in the river are old and nearing the end of their functional life. The riparian forest is not yet capable of providing a natural source of LWD. The channel width in the vicinity of the proposed structures was about 20 m with 0.3 m bank height, and average channel gradient was 0.55%.

Assessments and Prescriptions
A modified Level 1/Level 2 assessment was conducted in March 1999 by LGL Ltd. and the Haida Fisheries Program (HFP) and a list of high, moderate and low priority sites was generated (LGL/HFP April, 1999). This report outlined general prescriptions (including typical structures) for 25 high priority sites for instream work. The prescriptions for the Copper River Mainstem focused on LWD placements to promote pool scour, stabilize banks and provide instream cover. Due to limited funds and the large size of the river, two sites with good road access, were selected as a pilot project for completion in the 1999 field season.

Rehabilitation Work
The two sites (sites 3 and 4) selected for instream work in 1999 were located approximately 600 m apart. Both sites were located within 20 m of the South Bay Mainline. At site 3, eight large red cedar and cypress (*Chamaecyparis nootkatensis*) logs, 4 with rootwads attached, and six spruce stumps were used to create a structure on an outside bend. Most of the stems had one end attached to live trees on the bank while the other end on the riverbed was ballasted with rocks attached by cable and epoxy (Fig. 6–1).

At site 4, eight large red cedar and cypress logs were used to create a floating logjam that provides instream cover at the tailout of a large pool. This structure was constructed using four logs that had one end attached to live trees on the bank. The remaining four logs were placed over and under these logs at an angle to form a series of triangles with the logs pinned together using rebar (Fig. 6–2). At both sites a Hitachi EX150 excavator was used to place the LWD and boulders. The LWD used for this project was salvaged from a clearcut and delivered using a self–loading logging truck.

Cost Summary

Supervision and Reporting	$ 4,400
Labour	1,400
Materials and Equipment	5,000
Total Cost	$10,800

Outputs
The two structures are providing good cover for both adult and juvenile salmonids with juvenile fish observed around both structures within a few hours of completion. The

structure at site 3 is also creating some scour and should result in the formation of a good low water holding and rearing area.

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Figure 6–1. In Copper River mainstem, rocks attached by cable and epoxy ballasted the structures.

Figure 6–2. The triangulated structures were formed by using a series of triangles with the logs pinned together using rebar.

15K CREEK SLIDE BIOENGINEERING

Objectives
The objective of the 15K Creek Slide Project was to rehabilitate seven slides that contribute excessive amounts of sediment and debris into 15K Creek.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Ian Dodd, R.P.Bio.

Proponent/Implementing Partners
Husby Forest Products Ltd.

Watershed/Stream
Davidson Creek/Torney Creek

Location
Davidson Creek is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. 15K Creek is a large S2 creek that flows east into Davidson Creek. The slides can be accessed from the Eden Lake Logging Camp by travelling to the km 12.5 mark on the Davidson mainline then exiting onto Branch 50 and travelling to the km 14 marker.

Introduction
The Davidson Creek Watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystem) has sustained logging for the last 30 years. The watershed has been extensively logged during this time. Logging practices have initiated slides that impact fish streams and therefore rehabilitation measures have been investigated.

Assessments and Prescriptions
After completing a Level 1 Detailed Field Fish, Fish Habitat and Riparian Zone Assessment in 1998, the 15K Creek Reach 1 Section 2 slides were selected as possible restoration sites. The slides are located on side slopes to the creek. The top section of the slide slopes has been harvested in the past 15 years. Logging debris was left at a couple of landings located on the break in the slope. In a number of cases the logging debris initiated the slides. The slides have created logjams and sediment wedges in the creek. The slide paths have not revegetated and fine sediment continues to be deposited into the creek.

In 1998 bioengineering was conducted on four of the slides. This year bioengineering techniques were applied to slides 15K–2 and 15K–3; the two larger slides which were not addressed in 1998.

Rehabilitation Work
Works were initiated in July of 1999, and the following steps were taken:

- The spur road above the slides was deactivated in 1998. During the deactivation, logging debris was pulled back from the break in the slope below the road.
- Rebar, boards Sitka alder (*Alnus sinuata*) plugs and fertilizer were carried to the slides. Willow was not used because it is scarce in this area.
- Modified Brush Layers (MBL) were rebarred into place on the steeper sections of the slide (Figs. 6–3, 6–4 and 6–5). The brush layer consisted of Sitka alder plugs that were planted 30 cm apart. Sitka alder plugs were also planted on the slope between the MBLs. Live gully breaks were not used. The MBLs were extended into the gullied section of the slide to prevent further gully development. The MBL in the gullied section contained only cobbles to allow water passage.

Cost Summary

Personnel	$14,000
Equipment	1,000
Materials	1,000
Total Cost	$16,000

Outputs
Reach 1 Sections 1 and 2 of 15K Creek provide high quality rearing and spawning habitat for coho, pink, cutthroat and Dolly Varden. The slides have terminated in the creek creating large jams and sediment wedges. The jams do not prohibit fish passage. Downstream the channel is moderately to severely aggraded with dewatered channels during low flows. The bioengineering will reduce the amount of further sediment delivery to the creek. Bioengineering techniques were used on 0.4 ha of slide area.

Proposed Work

In the spring of 2000 re–seed exposed soils and repair damaged structures.

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Figure 6–3. Construction view of bioengineered landslide.

Figure 6–4. Construction view of bioengineered landslide.

Figure 6–5. Construction view of bioengineered landslide.

LOWER DAVIDSON OFF-CHANNEL CONSTRUCTION

Objectives
The objective of this project was to improve summer and winter rearing habitat for coho in a gravel pit pond.

FRBC Region/MELP Region
Pacific/Skeena/Vancouver

Author
Ian Dodd, R.P.Bio.

Proponent/Implementing Partners
Husby Forest Products Ltd.

Watershed/Stream
Davidson Creek/Torney Creek

Location
Davidson Creek is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. The pond in the gravel pit drains into Torney Creek close to the confluence of Torney and Davidson Creeks. Rehabilitation works were conducted within the confines of the abandoned gravel pit.

Introduction
The Davidson Creek Watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystem) has sustained logging for the last 30 years. The watershed has been extensively logged during this time. Logging practices have impacted coho off-channel habitat and therefore rehabilitation measures have been investigated.

Assessments and Prescriptions
After completing a Level 1 Detailed Field Fish, Fish Habitat and Riparian Zone Assessment in 1998, the Lower Davidson gravel pit pond was selected as a possible restoration site. Currently the pond provides rearing habitat but lacks depth and adequate fish cover.

The pond is tidal; U-shaped, 250-m long and 18-m wide. The pond is shallow with a low water depth averaging less than 40 cm and no overhead cover. Coho fry, stickleback (*Gasterosteus spp.*) and sculpin have been fish-trapped. Summer water temperatures have exceeded 25°C resulting in coho fry mortality.

Lister and Finnigan (1997) recommend developing ponds with a depth greater than 1.1 m, a surface area of less than 0.3 ha, and providing overhead cover.

Rehabilitation Work
The pond was excavated to a depth of between 1.5 and 2 m below the low water mark (Figs. 6-6, 6-7 and 6-8). The two ends of the pond were left at a depth of 40 cm to provide a variety of habitat depths. Three long slender islands were built to increase the edge area in the pond. The side slopes on the pond excavation have 1 horizontal to 1 vertical slope in an attempt to provide bank stability. Fifteen rootwads and 60 logs were placed in the pond for cover. Small trees and branches collected from a previous tree spacing project were added to the pond as cover. Following the excavation the exposed soils were grass seeded.

The following steps were taken to excavate the pond and add the LWD:

- The LWD was stockpiled at the landing to the south of the pit.
- The site was flagged indicating excavation limits, islands and the centreline.
- A large sandbag dam was placed at the mouth to the pond to prevent tidal water from entering the pond.
- Fish were removed by fry trapping, pole seining, beach seining and electrofishing.
- Using the Hitachi 200 excavator, a road was built into the pit for gravel truck access.
- Three gravel trucks were used to transport the material to two dumping sites.
- The LWD was put in place as the excavation progressed throughout the pond.

Cost Summary

Personnel	$10,300
Equipment	9,080
Materials	9,400
Total Cost	$28,780

Outputs
This project has created approximately 4500 m^2 of high quality rearing and overwintering habitat.

Production Estimates

Keeley *et al.* (1996) provided predictions of 69 coho smolt per 100 m^2 off–channel ponds. The pond is expected to produce approximately 3105 coho smolts annually. Keeley *et al.* (1996) provided predictions of 6.8 adult coho salmon per 100 m^2 off–channel ponds. Expected production of adults is approximately 306 coho.

Proposed Work

Re–seed exposed soils and add additional slash and branches for fish cover.

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Figure 6–6. Post–construction view of off–channel pond (prior to dam removal).

Figure 6–7. Post–construction view of off–channel pond (prior to dam removal).

Figure 6–8. Post–construction view of off–channel pond (prior to dam removal).

UPPER DAVIDSON GRAVEL BAR STABILIZATION

Objectives
The objective of this project was to stabilize gravel bars by planting red alder plugs. Windthrow had caused bank disturbance and sediment accumulation on gravel bars of the channel.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Ian Dodd, R.P.Bio.

Proponent/Implementing Partners
Husby Forest Products Ltd.

Watershed/Stream
Davidson Creek/Torney Creek

Location
Davidson Creek is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. The upper part of Davidson Creek is a medium sized S2 creek that flows northeast. The affected stream section is approximately 1500 m long. The stream section can be accessed by travelling southwest on the Davidson Mainline and turning left onto the branch road that enters Cutblock 413 Block 1. Follow the branch, cross the first bridge, and park at the first vehicle pull–out on the left hand side. The downstream end of the treated stream section is located by walking approximately 70 m to the east of the vehicle pull–out. The treated area is approximately 500 m long.

Introduction
The Davidson Creek Watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystem) has sustained logging for the last 30 years. The watershed has been extensively logged during this time. Within Cutblock 413 the riparian buffer along the west side of Davidson Creek is not wide enough resulting in windthrow.

Assessments and Prescriptions
After completing a Level 1 Detailed Field Fish, Fish Habitat and Riparian Zone Assessment in 1998, the Upper Davidson Reach 4 was selected as a restoration site. The following is the stream description:

- S2 stream (average width = 7.9 m), riffle–pool morphology, average gradient 2.3%, gravel dominated substrate.
- Cutthroat and Dolly Varden trapped.
- Streamside harvesting on the west bank leaving a one tree width riparian strip.
- Significant windthrow impact, bank erosion, and sediment accumulation in sediment bars.
- Lacks pool area and frequency.

This prescription involved the planting of large alder plugs on the exposed sediment bars.

Rehabilitation Work
Works were initiated in July of 1999. The red alder plugs were planted during summer low flows. The alder were planted 1 metre apart. Alder was also planted on any exposed and eroding banks.

Cost Summary

Personnel	$4,000
Materials	1,000
Total Cost	$5,000

Outputs
Approximately 600 red alder plugs planted along 500 m of stream.

Proposed Work
In the year 2000 the percentage of alder survival will be assessed. If the survival rate is high, another 1200 red alder plugs will be planted in the remaining 1000 m of disturbed channel.

For Further Information

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DEENA RIVER LWD PLACEMENT

Objectives
This project will improve spawning, rearing and overwintering habitat for salmonids (primarily coho as well as pink, chum and steelhead) in Weeping Willy Creek, a major tributary to the Deena River.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
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Proponent/Implementing Partners
JS Jones Ltd.

Watershed/Stream
Deena River/Weeping Willy Creek

Location
The Deena River is located on Haida Gwaii in the southwest corner of Skidegate Inlet on Moresby Island. The work site can be reached by travelling the JS Jones logging roads to West Deena Mainline. The work site is located on a major tributary (Weeping Willy Creek), which crosses the West Deena Mainline at 5.0 mile.

Introduction
The Deena River has been extensively logged over the past 40 years. Approximately 90% of the Weeping Willy sub–basin has been logged since the late 1960s. A combination of high annual rainfall, unstable terrain and extensive timber harvesting have caused numerous landslides and significant channel instability in both the tributaries and the mainstem. Changes in the main channel and numerous small tributaries have resulted in the loss of rearing and overwintering fish habitat. Coho salmon, important to the commercial and recreational fisheries, is the primary target species for rehabilitation.

Restoration works were conducted on three upper tributaries of the Deena in 1997 and 1998. The reach had a channel width of 8 m, an average bankfull depth of 0.7 m, and average slope of 1.7%.

Assessments and Prescriptions
Level 1 assessments were conducted in 1998 by LGL Ltd. and the Haida Fisheries Program (HFP) resulting in a list of high, moderate and low priority sites for rehabilitation (HFP/LGL 1999). In January 1999 Level 2 surveys were conducted for most of the high priority sites by NHC Ltd. and HFP. Prescriptions were generated following these surveys and then summarized in a Level 2 prescription report (NHC/LGL 1999). For Weeping Willy Creek the prescription was to restore a natural meander pattern to the reach and to promote the formation of scour pools, stabilize banks and provide instream cover by placing LWD.

Rehabilitation Work
The 1999 works occurred on the lower 700 m of Weeping Willy Creek. Construction of 31 LWD structures and the manipulation of one LWD jam were proposed. The construction of LWD structures was implemented in four stages:

- Collection and delivery of logs and rootwads (LWD) from a clearcut approximately 10 km away. Wood was pulled to the roadside using a Hitachi EX150 excavator with an 8 m choker, then to the worksite using a self-loading truck. Rootwads were transported by a dump truck.
- Four short tote roads were built from nearby logging roads to the stream access points using an EX150 excavator. The routes for tote roads were selected to minimize impacts to the riparian zone. No conifers were removed, and when trees were removed they were felled by hand. Wherever possible the stumps were cut low and left in place to reduce ground disturbance.
- Approximate placement of LWD and rocks at the proposed structure locations used a skyline system. The skyline consisted of either a 60 m or 100 m length of 9/16–inch diameter galvanized steel cable securely anchored to a tree or stump at the far end, as close to the ground as possible. The near end of the cable was attached to the bucket of the EX150 excavator. Logs, rootwads and rocks were suspended from one or two pulleys. With the skyline cable tight and sloping down, the load was moved along by gravity. Once the load reached the designated location, the excavator boom was lowered to the ground. Rootwads were the most difficult to move in this way because of their tendency to get caught on surrounding trees.
- Construction of LWD structures was carried out by a crew of four workers. A single grip puller (Tirfor Jack) with a 1500 kg lifting capacity rating was used to pull the logs and rocks into place. In total, nine V–

shaped lateral spurs (Figs. 6–9 and 6–10), 10 cross stream sills and three rootwad cover features were installed. In addition, an LWD jam was manipulated to allow better fish passage and reduce lateral scour and potential avulsions. These structures were constructed and anchored using techniques described in Watershed Restoration Technical Circular No. 9.

Cost Summary

Supervision, Monitoring and Reporting	$23,000
Labour	6,800
Materials and Equipment	15,300
Total Cost	$45,100

Outputs

The instream structures have already increased the number of adult and juvenile holding areas throughout the lower 700 m of Weeping Willy Creek by creating areas of scour and cover around the LWD structures.

Proposed Work

An additional 11 V–shaped lateral LWD spurs and one log and rootwad bank protector/lateral debris jam will be constructed during 2000. For the structures which could not be completed because of time and budget constraints in 1999, the logs were either moved onto the banks or secured to live trees with rope or cable. The structures constructed during 1999 will be assessed and any necessary adjustments will also be made.

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Figure 6–9. Placing instream structures in Weeping Willow Creek is expected to increase the scour and cover for fish.

Figure 6–10. V–shaped lateral LWD spurs were placed in 11 locations in Weeping Willow Creek.

CLEAR CREEK SIDE CHANNEL

Objectives
The objective of this project was to improve and increase the fish habitat in a small stream that had formed in an old roadbed. This development was aimed especially at rearing habitat for coho, Dolly Varden and cutthroat trout.

FRBC Region/MELP Region/MOF Region
Skeena–Bulkley/Skeena/Prince Rupert

Authors
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Glenn Grieve, R.P. Bio.

Proponent/Implementing Partners
Kitsumkalum Band Council.

Watershed/Stream
Kitsumkalum River/Clear Creek

Location
The site is located near the village of Rosswood, approximately 50 km north of Terrace, BC on the Nisga'a Highway. The site can be reached by turning northeast from the highway onto Egan Road, travelling approximately 2.5 km and turning east onto Geier Road. From the end of Geier Road turn north along the old main logging road to Clear Creek. From there it is necessary to wade the creek and proceed north along the old road approximately 1 km to the site.

Introduction
This is the fourth year of what has become a five–year project. Work began in 1995 with a Level 1 overview study of the Kitsumkalum River Watershed which was followed by a Level 1 detailed assessment of the Clear Creek Watershed in 1996 and a feasibility study of this site in 1997. The project is focused on extending and improving the habitat in a 1.25–km long, groundwater–fed, sidewall channel that occupies the eroded bed of what used to be the mainline logging road. Water levels have varied less than 0.5 m, and water has flowed throughout the winter during the last two years of monitoring. Sediment size and water level fluctuations suggested that the side channel did not need to dissipate much energy even in relatively high water events in the watershed when it probably carries floodwaters distributary from the mainstem. The channel had very little complexity, and virtually no wood. Since the entire area had been greatly influenced by past logging activities, and due to its location, energetics and stable water supply, the project represented a relatively low risk with a significant potential to produce fish. This conclusion was apparently shared by all of the fisheries personnel who visited the area before construction began, including staff from the Ministry of Environment, Lands and Parks, Fisheries and Oceans Canada and the U.S. Forest Service.

Assessments and Prescriptions
A Level 1 field assessment and a feasibility study were completed in 1996–97. Construction design prescribed extension of the channel headward, using the excavation spoil to build a berm between the mainstem creek and the side channel development, and complexing most of the existing eroded stream channel with deep pools and LWD placement. As part of the feasibility study the entire floodplain topography was mapped using a total station, and a series of 46 benchmarks were established near the channel. The specific design of the lowest 250 m of the side channel has been postponed to date in order to assess the significance of a large beaver dam–wetland complex to fish passage over three years. As one of the beaver dams does appear to be blocking upstream migration of adult coho, this design will be prepared for construction next year, when the 1.25 km of habitat we've improved or created will finally be connected to the mainstem of Clear Creek. This Type III Site Survey and Design will require additional fieldwork and topographic surveys.

Rehabilitation Work
After erecting a temporary steel bridge, borrowed from the MOF, over the mainstem creek, the existing eroded channel was extended headward in 1998 by excavation of an additional 250 m of channel to a depth of 2 m below grade and an average wetted width of 5 m. The spoil from this excavation was used to construct a 1.5–m high, 5–m wide and 300–m long berm between the mainstem creek and the side channel. Before pulling out before the heavy fall rains, disturbed areas were seeded, silt control structures were built and the temporary bridge was removed.

In 1999 the mainstem creek had braided, necessitating the installation of two temporary bridges for access to the eastern side channel. The newly excavated channel, along with 120 m of the original, eroded former roadbed, were complexed by embedding 31 single–log, channel spanning, LWD weirs, excavation of deep pools, increasing the sinuosity of the channel and the placement of 139 other LWD pieces as cover and for bank protection. Disturbed areas have again been seeded, silt control has been established and the bridges have again been removed. As the project is not yet complete, only a preliminary survey of the location and orientation of installed structures was done using a hip chain, compass and clinometer, so that gross movements will be detectable.

All of the work to date has occurred in the headwater area of the side channel. We have approximately 900 m to go and are gradually working our way downstream.

Equipment

We used an EX200 Hitachi with a thumb, a Hitachi 160 and a John Deere 490 on the project this year. All three excavators had biodegradable hydraulic fluid. We found the largest machine to be most efficient for the complexing work. The bridge construction required approximately 41 hours and the placement work took approximately 62 hours. LWD was delivered using a single–axle flat deck truck with a Hiab crane.

Cost Summary

Equipment	
Access	$24,881
Complexing	16,188
Materials (170 pieces LWD)	1,500
Project Management/Reports	3,400
Total Cost	$45,969

Production Estimates

Approximately 1250 m^2 of new habitat was created and improved in the channel extension and an additional 480 m^2 of habitat was created and improved in the existing eroded channel. A conservative interpretation of bio–standards (Koning and Keeley, 1997) suggests that there is a potential for the work to date to result in the return of 103 adult coho, along with a 1.5–fold increase in production of cutthroat trout and Dolly Varden char.

Proposed Work

It is recommended that the complexing be continued and that the modifications near the mouth be designed and implemented. Any of the LWD that could float should be anchored to embedded LWD using manila rope.

The anchoring should be completed during the fall of 1999. The site survey and design will be completed in the spring of 2000, with continued complexing of the channel and the construction to provide fish access near the mouth slated for later that summer.

For Further Information

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GLACIER CREEK FAN STABILIZATION

Objectives
The objective of this project is to improve and stabilize the Glacier Creek fan located at the confluence of the Kitsumkalum River and Glacier Creek.

FRBC Region/MELP Region/MOF Region
Skeena–Bulkley/Skeena/Prince Rupert

Author
Lyle Bolton

Proponent/Implementing Partners
Kitsumkalum Band Council (KBC).

Watershed/Stream
Kitsumkalum River/Glacier Creek

Location
Glacier Creek is a small tributary that flows into the Kitsumkalum River 10 km south of Kitsumkalum Lake. The creek crosses the Nisga'a Hwy approximately 25 km north of Terrace.

Introduction
Glacier Creek flows west into the lower Kitsumkalum River approximately 26 km upstream from the Skeena–Kitsumkalum confluence. The watershed drains approximately 15.5 km^2 of the western slopes of the Hazelton Mountains in the Nass Range. The mainstem is approximately 10 km long. An upstream migration barrier (~350 m from the confluence) limits anadromous fish from using the upper reaches of the creek.

Assessments and Prescriptions
Glacier Creek was included in the Kitsumkalum Watershed Restoration Program. Initial biophysical planning and assessment (J&S Outdoor Ventures Ltd., 1996), stream inventory and a Level 1 fish habitat assessment were conducted by Jim Culp. The WRP Level 1 fish habitat assessment identified coho and Dolly Varden at the highway bridge. Cover features (i.e., LWD, boulders, off–channel and overhanging vegetation) in this reach rated poor to fair (J&S Outdoor Ventures Ltd., 1996).

Rehabilitation Work
The restoration of Glacier Creek occurred largely at the section below the Nisga'a Hwy bridge. This section of the creek appeared to have been channelized and severely lacked habitat diversity (Fig. 6–11).

LWD was placed at approximately 16 locations along the lower part of the creek fan. A EX200 excavator was utilized in the placement of the LWD. After the wood was put in place they were then pinned together with 5/8–inch rebar and tied together with biodegradable (manila) rope. The completed project has created pools for fish habitat.

The fan stabilization at this site will improve access upstream from the confluence of the Kitsumkalum River and Glacier Creek and prevent degradation of the channel bed.

Stabilizing the lower part of Glacier Creek has created more diversity and habitat conditions (Fig. 6–12). It also provides more water depth during low flow periods. The works will be monitored over an extensive period of time by taking photographs of the area. The pools will provide holding cover for spawners and rearing habitat for juvenile and resident salmonids.

Cost Summary

Labour	$7,213
Equipment and Materials	1,918
Total Cost	$9,131

Outputs
0.5 km of stream was restored.

Production Estimates
Production estimates for this project have not yet been determined.

Proposed Work
Glacier Creek is the site of a potential fish habitat area that is in the initial working stages. The work as mentioned earlier will be monitored with photos over the next several years.

For Further Information
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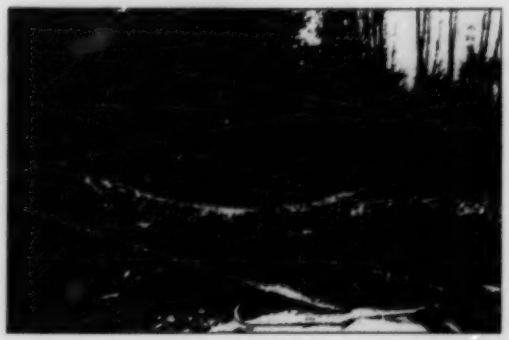

Figure 6–11. Complexing at Glacier Creek in progress.

Figure 6–12. Placement of LWD at Glacier Creek.

MATHERS CREEK TRIBUTARY RESTORATION

Objectives
Improve adult holding and juvenile rearing and over wintering habitat for salmonids (primarily coho as well as sockeye, chum, pink and steelhead) in lower Mathers Creek.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Leandre Vigneault

Proponent/Implementing Partners
MacMillan Bloedel Ltd.

Watershed/Stream
Mathers Creek/Clew Creek

Location
Mathers Creek is located on Haida Gwaii on the north side of Louise Island. The work site can be reached by driving east from Beattie Camp along the Louise Mainline to the junction with spur L300. Some of the work was conducted immediately adjacent to this junction (Clew Creek) and some at the 7–mile mark on L300 (Tributary 2.0 LB).

Introduction
Mathers Creek flows east from the northern–central part of Louise Island and empties into Cumshewa Inlet southeast of Kitson Point. Mathers Creek is the largest watershed on Louise Island with a drainage area of 84.2 km^2. The watershed supports runs of coho, sockeye, chum and pink salmon as well as steelhead and cutthroat trout and Dolly Varden char. Approximately 26 km^2 (30%) of the watershed has been logged with most of the logging concentrated in the lower mainstem and the two major tributaries. Most of this logging was done prior to the 1970s and has resulted in loss of most of the old growth riparian forest along the lower mainstem. A combination of increased sediment loads and reduced LWD input has resulted in a loss of good adult holding and juvenile rearing habitat in the Mathers Creek mainstem and tributaries.

Clew Creek has an 8 m channel width, 2 m depth, and average slope of 2.3%. Tributary 2.0 LB was considerably smaller with an average channel width of about 3 m.

Assessments and Prescriptions
Level 1 assessments were conducted in August 1998 by LGL Ltd. and the Haida Fisheries Program (HFP) resulting in a list of high, moderate and low priority sites for rehabilitation (LGL/HFP March, 1999). Level 2 surveys were conducted for most of the high priority sites in January 1999 by NHC Ltd. and HFP. Prescriptions were generated following these surveys and then summarized in a Level 2 prescription report (NHC/LGL, 1999).

Rehabilitation Work
Recommended rehabilitation works for Mathers Creek focused on restoring off–channel areas and adding LWD cover elements. Work in the 1999 field season focused mainly on two sites, Clew Creek and Tributary 2.0 LB. As well, two large trees that had slumped into the mainstem from an eroding bank were moved and securely anchored alongside the bank so as to continue to provide cover while limiting any threat to a bridge.

Clew Creek
Instream work was conducted in the lowest reach of this creek, downstream of the Louise Mainline road crossing. The lower 175 m of this reach had only a few pieces of LWD, primarily clumps of alder fallen from the stream bank and was characterized by mid–channel bars, eroding banks and multiple flow channels. The objective was to return the creek to its previous channel alignment, add LWD to scour pools and provide instream cover as well as prevent further bank erosion. A Hitachi EX300 excavator was used to excavate and re–establish the original channel, construct a large woody debris (LWD) jam to block off an avulsion channel, bury LWD sills to maintain grade control and place LWD for scour and bank protection. A four person crew assisted to install 8 LWD structures including V–shaped structures on the bank to deflect flow and create scour, sill logs to control the grade of the streambed (Fig. 6–13 and 6–14), and other log structures to block avulsion channels and maintain the preferred channel alignment.

Tributary 2.0 LB

Instream work was conducted by hand in the lower 400 m meters of this creek. A four–person crew worked with hand tools to excavate pools, install LWD sills to backwater pools and construct LWD structures to provide instream cover (Fig. 6–15).

Cost summary

Supervision, Monitoring and Reporting	$33,200
Labour	10,400
Materials and Equipment	27,355
Total Cost	$70,955

Outputs

The instream work completed at the two sites resulted in improved fish access as well as direct fish habitat improvements to 575 m of stream channel.

For Further Information

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Figure 6–13. View looking upstream at a typical V–shaped log spur on Clew Creek.

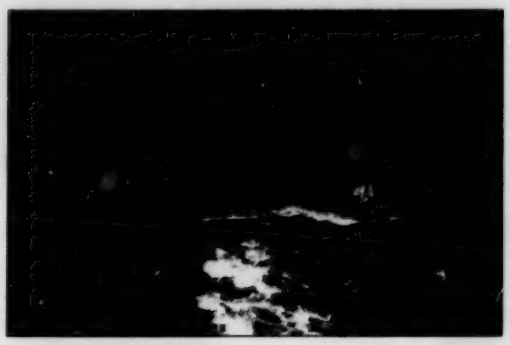

Figure 6–14. View looking upstream at a typical V–shaped log spur on Clew Creek.

Figure 6–15. View looking upstream at a rock riffle and two LWD structures constructed by hand in Tributary 2.0 LB.

CAMP CREEK INSTREAM STRUCTURES

Objectives
The purpose of the Camp Creek project was to increase habitat complexity for coho by adding functional large woody debris (LWD).

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Ian Dodd, R.P.Bio.

Proponent/Implementing Partners
Naden Harbour Timber Ltd.

Watershed/Stream
Naden River/Camp Creek

Location
Naden River is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. Camp Creek is a small S2 creek that flows east into Eden Lake. The creek can be accessed from the Eden Lake Logging Camp by walking south 50 m. The instream structures are located approximately 70 m downstream of the camp.

Introduction
The Naden River Watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystems has sustained logging for approximately the last 35 years. The watershed has been logged extensively during this time. Logging has affected fish habitat in a number of locations.

Assessments and Prescriptions
Camp Creek was harvested to the banks between 1977 and 1979. The creek now consists of sections of long riffles and lacks LWD and LWD recruitment. Fish utilization was low based on a pre-project assessment using minnow traps.

The project consisted of adding six triangle logjams/deflectors to a 150 m section of the creek (Figs. 6-16, 6-17). The structures were positioned to enhance existing shallow pools. A backhoe was used to place the logs and boulders in the creek.

Rehabilitation Work
Works were initiated in August of 1999, and the following steps were taken:

- Cedar logs were salvaged from roadsides and transported to a landing located close to the creek. Boulders from a quarry were transported to the landing site using a gravel truck. The logs weighed between 2000 and 3000 lbs and each boulder weighed between 400 and 700 lbs.
- A generator, an electric wood auger, and an electric rock drill were used at the landing to prepare the rock and logs for transport into the creek. Holes were drilled through both ends of the logs. Two 8-inch long holes were drilled into the boulders. The two ends of a 1/2-inch galvanized metal cable were fastened into the holes of two separate boulders using epoxy.
- The logs and rocks were transported to each creek site, where the hoe was used to place the structures. The hoe could access the stream at these sites with minimal damage to the riparian vegetation.
- For the next three days, the logs were re-positioned in the creek using hand winches. The logs and boulders were then cabled together in the creek.
- The logs do not extend more than 40% into the channel bankfull width. In most cases the logs were positioned in a low profile to prevent bank scour.

Cost Summary

Personnel	$8,000
Equipment	2,000
Materials	500
Total Cost	$10,500

Outputs
This project has created approximately 240 m^2 of high quality pool habitat. The 150 m section of complexed fish habitat is expected to produce approximately 500 0+ coho.

Proposed Work
Perform maintenance on structures. Remove large boulders from pools to deepen pools. At one location, build a sill log structure to hold back gravel.

For Further Information

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Figure 6–16. Post–construction view of a triangular logjam.

Figure 6–17. Post–construction view of a triangular logjam.

LOWER NADEN REACH 3–4 INSTREAM STRUCTURES

Objectives
The purpose of the Lower Naden Reach 3–4 Project was to increase habitat complexity for coho by adding functional large woody debris.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Ian Dodd, R.P.Bio.

Proponent/Implementing Partners
Naden Harbour Timber Ltd.

Watershed/Stream
Naden River/Lower Naden Reach 3–4 Creek

Location
Naden River is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. Lower Naden Reach 3–4 is a small S2 creek which flows north east into Naden River. The creek can be accessed from the Eden Lake Logging Camp by travelling north five kilometres on the Naden Mainline to the 10 km road sign. The road crosses the stream at this location. The instream structures are located immediately upstream and downstream of the stream crossing.

Introduction
The Naden River Watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystem) has sustained logging for approximately the last 35 years. The watershed has been extensively logged during this time. Fish habitat has been negatively affected by past logging practices in a number of locations.

Assessments and Prescriptions
Lower Naden Reach 3–4 creek was harvested to the banks between 1974 and 1977. The creek now consists of sections of long riffles and lacks LWD and LWD recruitment. Fish utilization was low based on pre–project assessment using minnow traps.

The project consisted of adding eight triangle log jams/deflectors to a 200 m section of creek. The logjams were positioned to enhance existing shallow pools. For the four structures upstream of the stream crossing, a helicopter was used to place the logs and boulders in the creek. For the four structures downstream of the stream crossing, a backhoe was used to place the logs and boulders in the creek.

Rehabilitation Work
Works were initiated in August of 1999, and the following steps were taken:

- The riparian zone is dominated by pole–sapling conifer, which provides 50% crown closure of the creek. Several conifers were removed from selected sites to provide a hole in the canopy for the logs and rocks to be lowered to the creek.
- Cedar logs were salvaged from roadsides and transported to a landing located close to the creek. Boulders from a quarry were transported to the landing site using a gravel truck. The logs used weighed between 1000 and 2500 pounds and each boulder used weighed between 300 and 700 pounds.
- A generator, an electric wood auger, and an electric rock drill were used at the landing to prepare the rock and logs for transport into the creek. Holes were drilled through both ends of the logs. Two 8 inch–long holes were drilled into the boulders. The two ends of a 1/2" galvanized metal cable were fastened into the holes of two separate boulders using epoxy.
- The logs and rocks were transported to the creek sites. A backhoe placed the structures at the four sites located downstream of the road crossing. The backhoe could access the stream at these sites with minimal damage to the riparian vegetation.
- A helicopter transported the material to the 4 sites located upstream of the road crossing. A Hughes 400 helicopter was used to transport the logs and boulders. The helicopter pilot was directed to each site by the radio–person in the creek. Good communication between the pilot and the radio–person was imperative since the pilot can not see the creek and the radio–person in the creek can not see the helicopter.
- For the next three days the logs were re–positioned in the creek by using hand winches. The logs and boulders were then cabled together in the creek.
- The logs do not extend more than 40% into the channel bankfull width (Figs. 6–18, 6–19, 6–20). In most cases the logs were positioned in a low profile to prevent bank scour.

Cost Summary

Personnel	$11,500
Equipment	3,500
Materials	1,000
Total Cost	$16,000

Outputs

This project has created approximately 320 m^2 of high quality pool habitat. The 200 m section of complexed fish habitat is expected to produce approximately 900 0+ coho.

Proposed Work

During 2000, it is proposed that maintenance be performed on the structures; the large boulders from pools should be removed to deepen pools; and two or three riffle structures upstream of existing structures are to be constructed.

For Further Information

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Figure 6–18. Post–construction view of a triangular logjam.

Figure 6–19. Post–construction view of log deflectors.

Figure 6–20. Post–construction view of log deflectors.

LOWER NADEN REACH 4–2 UPGRADE TO INSTREAM STRUCTURES

Objectives
The purpose of the Lower Naden Reach 4–2 Upgrade to Instream Structures Project was to secure and adjust the 1998 triangular logjam structures and to add five more large woody debris structures to increase habitat complexity for coho.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Ian Dodd, R.P.Bio.

Proponent/Implementing Partners
Naden Harbour Timber Ltd.

Watershed/Stream
Naden River/Lowre Naden Reach 4–2 Creek

Location
Naden River is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. Lower Naden Reach 4–2 is a small S2 creek that flows east into Naden River. The creek can be accessed from the Eden Lake Logging Camp by travelling north 0.5 km on the Naden Mainline to the first bridge crossing. The instream structures are located immediately upstream of the stream crossing.

Introduction
The Naden River Watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystem) has sustained logging for approximately the last 35 years. The watershed has been extensively logged during this time. Logging has negatively affected fish habitat in a number of locations.

Assessments and Prescriptions
Lower Naden Reach 4–2 creek was harvested to the banks between 1974 and 1979. The creek now consists of sections of long riffles and lacks LWD and LWD recruitment. Fish utilization was low based on pre–project assessment using minnow traps.

The project consisted of securing and adjusting five existing triangle logjam structures and adding five more structures to a 400 m section of creek (Figs. 6–21, 6–22, 6–23). The logjams were positioned to enhance existing shallow pools. A helicopter was used to place the logs and boulders in the creek.

Rehabilitation Work
Works were initiated in August of 1999, and the following steps were taken to adjust five of the existing structures:

- The existing structures were adjusted to enhance pool development. Hand winches were used to reposition the logs. Logs were not extended more than 40% into the channel bankfull width. Ballast rock was brought in by helicopter in order to support several structures.

The following steps were followed for adding the five additional structures:

- The riparian zone is dominated by pole–sapling red alder, which provides 100% crown closure of the creek. Alder was removed from each site to provide a hole in the canopy for the logs and rocks to be lowered to the creek.
- Red cedar logs with attached rootwads were salvaged from roadsides and transported to a landing located close to the creek. Boulders from a quarry were transported to the landing site using a gravel truck. The logs used weighed less than 1200 pounds and each boulder used weighed between 300 and 450 pounds.
- A generator, an electric wood auger, and an electric rock drill were used at the landing to prepare the rock and logs for transport into the creek. Holes were drilled through both ends of the logs. Two 8–inch long holes will be drilled into the boulders. The two ends of a 1/2" galvanized metal cable will be fastened into the holes of two separate boulders using epoxy.
- The logs and rocks were transported by helicopter to the creek sites. The helicopter pilot was directed to each site by the radio–person in the creek. Good communication between the pilot and the radio–person was imperative because the pilot could not see the creek and the radio–person in the creek could not see the helicopter.
- For the next three days the logs were re–positioned in the creek by using hand winches. The Hughes 500 helicopter then transported the boulders in pairs to each of the sites. The logs and boulders were then cabled together in the creek.

Cost Summary

Personnel	$9,000
Equipment	3,000
Materials	1,000
Total Cost	$13,000

Outputs

This project has created approximately 200 m^2 of high quality pool habitat. The 400–m section of complexed fish habitat is expected to produce approximately 1800 0+ coho.

Proposed Work

Perform maintenance on structures. Remove large boulders from pools in order to deepen the pools.

For Further Information

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Figure 6–21. Post–construction view of a triangular logjams.

Figure 6–22. Post–construction view of a logjam.

Figure 6–23. Post–construction view of a log deflector.

GREENVILLE CREEK INSTREAM RESTORATION

Objectives
The objectives of this project are to restore holding, rearing and spawning habitats for salmonids in Greenville Creek.

FRBC Region/MELP Region/MOF Region
Skeena–Bulkley/Skeena/Prince Rupert

Author
Bruce Murray

Proponent/Implementing Partners
Nisga'a Tribal Council.

Watershed/Stream
Nass River/Greenville Creek

Location
Greenville Creek enters the west side of the Nass River at the village of Lakalzap (Greenville). The 1999 restoration works are located in the west sub–basin of Greenville Creek, 1300–1700 m upstream of the Nisga'a Highway bridge crossing of Greenville Creek at the north entrance to the village of Lakalzap.

Introduction
Greenville Creek supports several salmonid species including coho, pink and chum salmon, Dolly Varden char and cutthroat trout. The drainage area of the west sub–basin is 26.5 km, of which 7.4% has been logged (NTC, 1996). Most of this logging occurred in readily accessible, riparian areas. Channel instability has limited both the quality and quantity of historic salmon, trout and char habitats used for spawning, egg incubation and juvenile rearing. Channel aggradation results in long periods of subsurface flow. This functions to reduce fish production by increasing juvenile mortality and delaying spawning run timing.

Assessments and Prescriptions
The Level 1 Fish Habitat Assessment (NTC, 1998) identified that riparian logging, stream channelization, dyking, and aggradation negatively impacted Reach 6b. Similarly, riparian logging, hill slope and channel instability and aggradation negatively impacted Reach 6c. Both reaches are over widened, have very poor pool area (<6%) and pool frequency (1 in 12 B_w), low numbers of functional large woody debris and are often subject to subsurface flows due to sediment aggradation.

The Level 2 Fish Habitat Restoration Prescriptions (NTC, 1999) addressed habitat impacts identified in the Level 1 assessment and targeted salmonid spawning, rearing and holding life stages. A total of 17 prescription sites were proposed; restoration activities were to:

- construct LWD and boulder structures at six sites in Reach 6c that would help realign the channel and maintain flows up to a bankfull stage within a single channel;
- establish a radius of curvature on the meanders of approximately 2.3–fold the bankfull width;
- re–establish a single channel in Reach 6b by constructing pool and riffle sequences at 11 sites;
- establish cover by constructing LWD structures in 18 newly established pools in Reaches 6b and 6c; and,
- revegetate the abandoned overflow channels in Reaches 6b and 6c with natural vegetation.

Rehabilitation Work
Two prescription sites were completed during the 1999 construction window. At Site 17 and Site 16, multiple LWD and boulders structures were constructed to realign the channel and provide overhead cover (Figs. 6–24, 6–25). At Site 17, a 14 x 8 m pool was excavated along the right bank meander to provide a residual depth of 0.8 m. The right bank was then reinforced with nine rootwads, eight cover logs and epoxy cabled to 42 boulders. All rootwads were positioned into the channel and oriented in a manner to smooth the radius of curvature; while, the bole ends were entrenched 12 m into the right bank. The factor of safety (FS_B) to compensate for LWD buoyancy was 3.41 (D'Aoust and Millar, 1999).

At Site 16, the channel was realigned and downstream sedimentation from an active slide extending above the left bank was reduced. A total of 23 rootwads and 7 cut–logs were epoxy cabled to 36 boulders and arranged to form 10 triangular structures, over a distance of 58 m along the toe of the slide. All rootwads were placed in the channel and oriented in a manner to smooth the radius of curvature; while, the bole ends were entrenched 10 m into the face of the slide. Terracing the toe of the slide and armouring it with boulder material excavated from the realigned channel further reduced active channel sedimentation. The

FS_8 to compensate for LWD buoyancy among the 10 triangular structures ranged from 1.5 to 4.9 (D'Aoust and Millar, 1999).

All machine work was conducted with a Cat 315L excavator. To complete this project within the construction window required a crew of five people.

Cost Summary

Construction and Materials	$24,420
Supervision, Design and Labour	24,786
Total Cost	$49,206

Outputs

0.1 km of fish access was restored
0.1 km of stream was restored.

Production Estimates

Successful completion of this project will potentially restore summer surface flow to approximately 3 km of channel. Biostandards are not well founded for complex projects of this scope and can only be properly evaluated through effectiveness monitoring. In the interim, a review of the literature suggests that a 100 to 200% increase (i.e., a 1– to 2–fold increase) in fish biomass is not unreasonable (Koning and Keeley, 1997).

Proposed Work

Prescription work outlined above is targeted for completion in 2003.

For Further Information

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Figure 6–24. Post–construction view of Site 17, Greenville Creek.

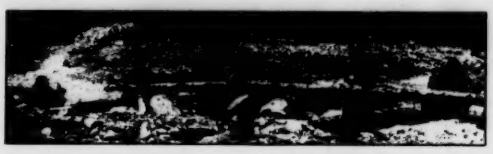

Figure 6–25. Post–construction view of Site 16, Greenville Creek.

GINLULAK CREEK INSTREAM RESTORATION

Objectives
The primary objective of this project is to control head cutting, thereby reducing streambank and streambed erosion. The secondary objective is to improve fish habitat.

FRBC Region/MELP Region/MOF Region
Skeena–Bulkley/Skeena/Prince Rupert

Author
Bruce Murray

Proponent/Implementing Partners
Nisga'a Tribal Council.

Watershed/Stream
Nass River/Ginlulak East Creek

Location
Ginlulak Creek is approximately 9.2 km long and drains a 43 km^2 watershed. Restoration work was restricted to the 15 km^2 Ginlulak East sub–basin. Ginlulak East Creek drains into the west side of a carex (*Carex spp.*) marsh from where it flows into the mainstem of Ginlulak Creek and then into the Nass River.

Introduction
Historically, the Ginlulak system supported annual runs of pink salmon, chum salmon, and coho. Dolly Varden char and cutthroat trout also inhabited the system. Pink and chum are rarely observed in the system, while coho salmon are still prevalent. Juvenile coho rearing habitat is replete; however, the most critical spawning habitat for the watershed is on the alluvial fan area of East Ginlulak Creek. This fan has been heavily impacted by past riparian logging practices. The majority of logging took place in the Ginlulak Watershed between 1954 and 1973. Logging in the Ginlulak East sub–basin accounts for 74% of all historic logging in Ginlulak Creek Watershed. To date, 37% of Ginlulak East sub–basin has been logged.

Assessments and Prescriptions
Logging of the fan has resulted in destabilization of the channel, formation of sediment wedges and frequent avulsions. A restoration plan proposed by nhc (1995) and implemented in 1996 re–established the creek in one main channel near the apex of the fan by:

- constructing a dyke to prevent the flows from continuing down a recent avulsion channel; and,
- removing a large sediment wedge from the main channel.

In 1997, the mainstem and off–channel habitat in the lower section of the fan was complexed with LWD and boulder structures (NTC, 1998). In 1998, coho escapement in this lower section of the fan was approximately 400 individuals, representing a 15–fold increase from 1997 (Bruce Baxter, pers. comm.).

A Level 2 Assessment conducted in 1998 (NTC, 1999) concluded that construction of pool and riffle sequences near the apex of the alluvial fan would:

- control channel head cutting and reduce the extent of bed and bank erosion during floods;
- extend the period of time the flow is on the surface of the streambed, rather than subsurface; and
- help stabilize and improve the quantity and quality or rearing, holding and spawning habitat for coho, Dolly Varden char and cutthroat trout.

Rehabilitation Work
Four boulder riffles structures were constructed with riffle spacing between 42 and 45 m or about four times the estimated bankfull channel width (Figs. 6–26, 6–27, 6–28, 6–29). Riffles were constructed with a 15 to 1 downstream face and featured a high roughness factor. Riffle crest heights ranged from 0.48 to 1.04 m. The riffle structures were built from a range of rock sizes (0.3 to 1.2 m mean ϕ). The largest rocks were selected to be stable at the maximum annual flood stage. Riffle crests were keyed into the streambed 0.2 to 0.5 m. Maximum depth of channel excavation of each scour pool, located at the toe of each riffle, was 1.4 m. Residual pool depth after armouring ranged from 0.85 to 1.2 m; while, residual depths in the four upstream dammed pools ranged from 0.96 to 1.4 m. A total volume of 530 m^2 of rock was used to construct four riffle structures.

Cost Summary

Labour	$ 8,137
Equipment and Materials	16,110
Total Cost	$24,247

Outputs

0.15 km of stream was restored.

Production Estimates

Biostandards for pool–riffle sequences are not well formulated. Pool and riffle sequences constructed in Ginlulak Creek in 1999 increased pool area approximately 4.5–fold, which parallels figures reported by Newbury *et al.* (1997) for pool–riffle construction in Oulette Creek on the Sunshine Coast. Fish biomass also increased 5.4–fold after restoration (Newbury *et al.*, 1997).

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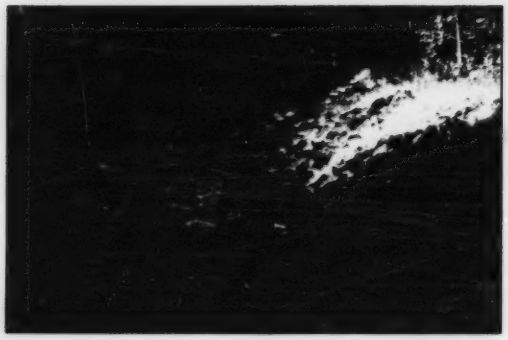

Figure 6–26. Downstream, pre–construction view from chainage 0+850 m at riffle crest site 1 (crest at 0+836 m) and riffle crest site 2 (crest in photo background at 0+791 m).

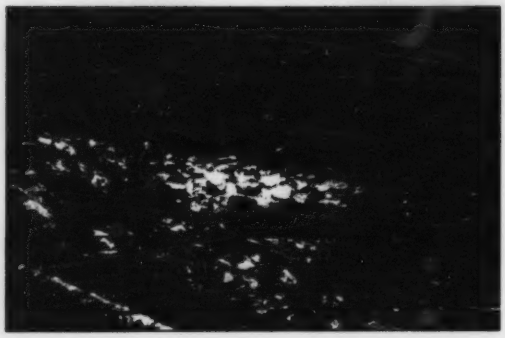

Figure 6–27. Upstream view of riffle and pool sequence at Site 1. Riffle crest is at chainage 0+836 m.

Figure 6–28. Upstream view of riffle and pool sequence at Site 2. Riffle crest is at chainage 0+791 m.

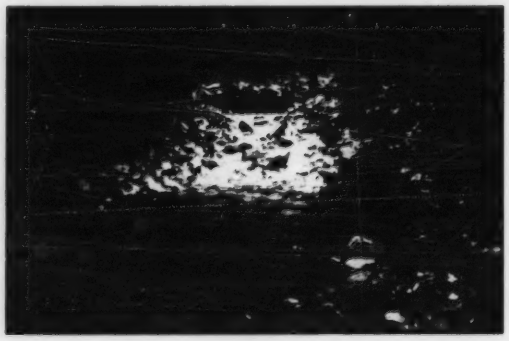

Figure 6–29. Upstream view of riffle and pool sequence at Site 3. Riffle crest is at chainage 0+746 m.

THORSEN CREEK RESTORATION PROJECT

Objectives

- Implement non–intrusive, cost–effective restoration strategies emulating existing natural processes and ensuring continuation of natural restorative processes occurring in the watershed;
- Implement restoration strategies acknowledging limiting factors to production of target species (coho, chum, pink, steelhead residents, respectively).

FRBC Region/MELP Region/MOF Region

Pacific/Skeena/Vancouver

Author

David Loewen

Proponent/Implementing Partners

Western Forest Products Ltd., Hecate Strait Streamkeepers.

Watershed

Thorsen Creek

Location

Sewell Inlet Moresby Island, Queen Charlotte Islands/ Haida Gwaii

Introduction

Thorsen Creek is a 1600 ha, fourth–order stream located in the submontane wet hypermaritime Coastal Western Hemlock (CWHwh1) ecosystem. Logging commenced in the watershed in the 1940s and continues today. Approximately 45% of the watershed has been logged with extensive logging and road building in the upper watershed. The combination of high precipitation (average 3,665 mm/year), steep valley walls, extensive logging and road building has led to extreme periods of flooding and mass wasting events throughout the watershed. A 15–m high logjam 1.84 km from the mouth (formed in 1984) has blocked all downstream migration of gravel and LWD and upstream migration of anadromous fish. A road parallels the lower 800 m of stream cutting off access to historical off–channel rearing areas.

Assessments and Prescriptions

Extensive local knowledge and assessments identified the following limiting factors:

- a lack of adequate spawning habitat;
- a lack of low velocity rearing/overwintering habitat;
- an increase in high water events; and
- a loss of accessible habitat.

Off–channel development was prescribed for four separate areas in reaches one and two to create rearing/ overwintering habitat, LWD placement at two sites in reach two to create rearing and spawning habitat, and boulder weir construction throughout reaches three and four to create spawning habitat and low–velocity rearing areas.

Rehabilitation Work

Work commenced in June 1999. Work included:

- A rearing/spawning channel constructed on the lower floodplain. A small tributary was utilized—lengthened by 75 m, widened over 50 m with a rearing pond (130 m^2) developed at the base of the valley wall (Off–channel #1) (Figs. 6–30, 6–31).
- A small rearing pond (130 m^2) was constructed immediately adjacent to a small tributary 765 m upstream of the mouth (Off–channel #2).
- An 800 m^2 rearing channel was excavated in an old filled–in back channel 811 m upstream of the mouth (Off–channel #3).
- Numerous boulder weirs were constructed throughout reaches 3 and 4 (Fig. 6–32).
- Two LWD structures were constructed in reach two, 0+374 m and 0+434 m (Fig. 6–33).
- Steps were taken to limit sediment input from the Metric M/L into Thorsen mainstem.

Cost Summary

Assessments and Prescriptions	$23,000
Construction, Supervision, Labour and Materials	62,000
Total Cost	$85,000

Production Estimates

Koning and Keeley (1997) suggest an 8.5–fold increase may be expected in chum and pink densities following mainstem spawning habitat restoration. It is difficult to apply a number to habitat created by the LWD structures and boulder weirs. Thorsen Creek is a very powerful stream during high water events; this winter will test the stability of the structures and dictate how many rearing and spawning habitats are created.

Koning and Keeley (1997) also suggests no other instream factors or bottlenecks should limit fish productivity. The 15–m high logjam at 1.84 km stops downstream migration of gravel therefore slowing development of spawning habitat. Ongoing monitoring of the mainstem structures would provide an accurate measure of habitat creation.

Off–channel development during this project created approximately 1500 m^2 of rearing/overwintering habitat. As coho numbers are currently very low in Thorsen Creek, the biostandards estimate of 6.8 adult coho per 100 m^2 off–channel pond or 102 adult coho for this project may be optimistic. Similar to the mainstem work, an ongoing monitoring program would provide an accurate measure of fish production from the developed off–channels.

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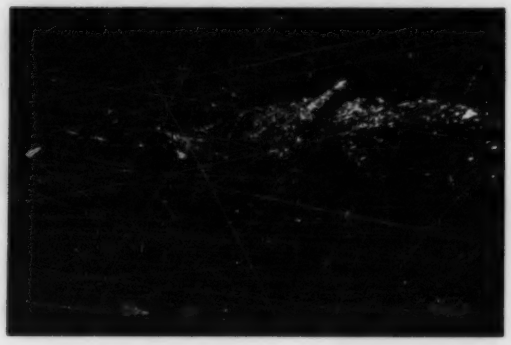

Figure 6–30. The downstream end of Off–channel #1. Depth in this area is approximately 1.5 m.

Figure 6–31. The upstream end of Off–channel #1. Any trees knocked down during construction were utilized to provide cover.

Figure 6–32. This boulder weir was constructed in reach 3. The main objective is to capture gravel moving downstream, however low velocity rearing habitat has also been created. The majority of the weirs were cabled together for much needed stability.

Figure 6–33. This LWD structure was constructed in reach two, 375 m upstream of the mouth.

CLAY CREEK BIOENGINEERING

Objectives
The objective was to reduce sedimentation occurring from a 405 m ditchline that couples into Clay Creek, a major spawning/rearing tributary of the Yakoun River Watershed, Queen Charlotte Islands. The project focused on the construction and installation of several bioengineering methods utilizing a broad cross–section of plant species.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Prince Rupert

Author
Darren Hebert, DWH & Associates

Proponent/Implementing Partners
Weyerhaeuser Canada Ltd.

Watershed
Yakoun River, Queen Charlotte Islands

Location
Clay Creek sub–basin, 25 minutes due south of Port Clemens, BC along East Yakoun Main road within TFL 39.

Introduction
In general, Clay Creek downstream of the ditchline is subject to high degrees of sedimentation and aggradation resulting from the erosion of lacustrine soils within the ditchline. The ditchline is highly prone to perennial surface and rill erosion, as evidenced by the numerous sediment wedges found throughout the downstream portion of Clay Creek. To that end, this site was proposed for rehabilitative works during the 1999/2000 field season.

Assessments and Prescriptions
The initial assessment of this site involved a determination of site elevation, exposure (aspect), as well as nutrient availability (based on soil type/biogeoclimatic zone type) and presence of indicator plant species. Based on this initial assessment, a restoration strategy involved an initial planting using pioneering woody species to restore slope stability. It is then recommended to underplant in later seasons using later successional conifer species such as western red cedar or Sitka spruce.

Methodology
In total, 230 m of ditchline will be treated with a combination of live smiles and wattle installations. All bioengineering works were constructed and installed employing hand labour. Live smiles were built and installed in the lower 37 m of the ditchline, while modified brush layers and wattle installations will occur from 37 m to 230 m upslope through the ditchline. The general strategy for this site involves halting further erosion of lacustrine soils into Clay Creek by protecting the exposed soils (wattles), and reducing the slope length and steepness (wattles and live smiles) through the ditchline. The lacustrine soils hold moisture well and are therefore conducive to the establishment of pioneering plant species (i.e., willow).

The plant species used for initial slope stabilization were varied, with the site restoration being viewed largely as an experimental trial at site propagation employing a wide variety of plant species. To that end, the prescription included the propagation of Pacific willow (*Salix lasiandra*), salal (*Gaultheria shallon*), kinnikinnick (*Arctostaphylos uva–ursi*), hardhack (*Spiraea douglasii*), salmonberry (*Rubus spectabilis*), Sitka willow (*Salix sitchensis*), red elder (*Sambucus racemosa*), and snowberry (*Symphoricarpos albus*). Each structure was tagged and recorded and will be assessed in 2000/2001.

Equipment
The project tools and handtools included: shovelnose shovels, planting shovels, swede saws, chainsaw, single–handed pruning shears, two–handed pruning shears, deadblow sledgehammers, hardhats, bailing twine, wattle sawhorses, dibbles, workglove, 10–gallon buckets, watering cans, safety equipment (hardhats, workgloves, eye shields/ear protection, hi–vis vests, level 1 first–aid kit, hand–held radios.

Rehabilitation Work
This bioengineering project, including site preparation, construction of structures, and installation spanned 14 days from October 12 to October 29, 1999.

The total area of treatment was 0.23 km or 2025 m^2 of ditchline and associated hillslopes (Figs. 6–34, 6–35). The project employed four technicians for a total of 56 person–

days. The project site was comprised of four separate rehabilitation sites (sites A, B, C, D). Total number of structures built and installed:

Site A:
Live Smiles: eight installed, each is comprised of 20, four–foot lengths of Pacific willow cuttings, 0.05 to 0.2 m in diameter. Cuttings all have side branches removed at trunk base. Total number of four foot cuttings: 160.

Rebar stakes: 32, 1 m lengths of rebar. Rebar posts are spaced 0.75 m apart in concave formation (facing open "upstream" in the ditchline).

Site B:
Total wattles installed: 9, 2 m in length, 0.15 m in diameter. Three rows of wattles, 1 m apart laterally, 2 m apart longitudinally. Each wattle row spans the length of the Site B sidewall failure. Fifty–four stakes were required. Total modified brush layers: 22, each 1 m length (faceplate) with >10, 1 m length cuttings.

Site C:
Total wattles installed: 9, 2 m in length, 0.15 m in diameter. Three rows of wattles, 1 m apart laterally, 2 m apart longitudinally, starting at 0+41. Each row spans the length of the Site C sidewall failure. Twenty–seven stakes were required. Total modified brush layers: 9, each 1 m length (faceplate) with >10, 1 m length cuttings.

Site D:
Total wattles needed: 120, 2 m in length, 0.15 m in diameter. Two rows of wattles, 1 m apart laterally, 2 m apart longitudinally, starting at 0+56. Each row spans the length of the Site D sidewall failure. Three–hundred and sixty stakes were required. Total modified brush layers: 33, each 1 m length (faceplate) with >10 1 m length cuttings.

Cost Estimates

Four Technicians	$ 7,616
One Project Manager	4,900
Two vehicles	2,800
Field Supplies	500
Total Cost	$15,816

Monitoring

Maintenance is proposed for the 2000/2001 field season. In particular, an assessment of each plant species tagged during construction/installation will be carried out. General site maintenance and protection will also be conducted during the next fiscal year.

For Further Information

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Figure 6–34. Panoramic view of Clay Creek (Y–1900) debris slump pre–work, August, 1999.

Figure 6–35. Panoramic view of Clay Creek (Y–1400) ditchline post–construction, December, 1999.

ZYMOETZ RIVER CULVERT REPLACEMENT (SITE 77)

Objectives
The objective was to re–establish juvenile fish access to a 1500 m² off–channel slough, used as rearing and overwintering habitat by juvenile coho, which was isolated from the river by two perched culverts in the road.

FRBC Region/MELP Region/MOF Region
Pacific/Skeena/Vancouver

Author
Steve Jennings

Proponent/Implementing Partners
Skeena Cellulose Inc.

Watershed/Stream
Zymoetz (Copper) River

Location
The culvert replacement occurred at 28 km on the Copper River Forest Service Mainline, approximately 45 km southeast of Terrace.

Introduction
The Copper River drains a 3000 km² watershed, which contains substantial fisheries values along with powerlines, pipelines, roads and forestry development. In conjunction with floodplain logging and road construction over the past 35 years, large floods caused substantial channel changes and impacted fish habitat, particularly off–channel habitat amount and fish access.

Assessments and Prescriptions
The slough at Site 77 is an isolated relic flood channel of the river, 200 m length and 7 m wide, located against the hillside and isolated from the river by the mainline road (Fig. 6–36). A small tributary and groundwater seepage maintains water levels in the slough.

The problem consisted of two culverts, perched 50 cm above the floodplain on the upstream and downstream ends, which were accessible to juvenile fish only when backwatered during river high flows (Fig. 6–37). Hundreds of juvenile coho were observed holding in the slack water below the culvert outfall during high runoff with no access to the off–channel habitat. Minnow trapping in the slough captured several coho smolts (160 to 180 mm in length) which were likely 3 years old and not able to exit the slough due to dispersed flow through the roadbed and perched culvert inlet. In addition to the metal culverts, an obstructed wooden box culvert was found during excavation, which dispersed water into the roadbed and prevented fish movement.

Rehabilitation Work
In August of 1999, we replaced the two perched culverts with a 1500 mm culvert that ensured up and downstream fish passage and removed the box culvert to maintain adequate water depth in the slough upstream (Figs. 6–38, 6–39).

The two 40 ft culverts were removed with an excavator working from the road. The roadbed was excavated an additional three feet lower to accommodate the 1500 mm baffled culvert (55 feet in length). The new pipe was installed at 1% slope and clean gravel and riprap armoring was placed around the inlet and outlets. Beaver grating will be installed.

Cost Summary

Labour	$ 5,000
Machinery and Materials	7,000
Total Cost	$12,000

Production Estimates
Overall the slough appears suitable as off–channel rearing habitat and we anticipate high use of the slough by coho fry which will be monitored. Average production is estimated at 375 smolts, using 0.25 smolts/m², similar to Telkwa River off–channel habitat production figures (A. Baxter, pers. comm.).

Proposed Work
Future work includes development of an outlet channel, 50 m in length, which will confine the culvert outflow across the floodplain to the river channel and ensure year–round access to the culvert exists for juvenile fish.

For Further Information

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Figure 6–36. Isolated off–channel slough located upstream of perched culverts at 28 km.

Figure 6–37. Outlet of two culverts perched 50 cm above the bed and only accessible at high flood river flows (inlet to left culvert buried).

Figure 6–38. Installation of new 1500 mm culvert.

Figure 6–39. The new culvert provides upstream access to off–channel habitat and enables downstream migration of smolts.

FENTON CREEK FISH ACCESS PROJECT

Objectives
The objective of this project was to re-establish fish access to the middle and upper reaches of Fenton creek that were cut off by a wooden stave culvert constructed in the early 1960s.

FRBC Region/MELP Region/MOF Region
Skeena-Bulkley/Skeena/Prince Rupert

Author
Jeff Lough

Proponent/Implementing Partners
Houston Forest Products

Watershed/Stream
Morice River/Fenton Creek

Location
Fenton Creek is a tributary of the Morice River. It flows into the Morice at approximately km 30 on the Morice River Mainline

Introduction
Fenton Creek currently contributes 500 m of summer run steelhead and coho habitat in its lower-most reach. A mainline logging road culvert located approximately 500 m upstream of the confluence has been blocking all fish passage to approximately seven kilometres of stream since the early 1960s. Fish sampling downstream of the culvert has identified significant densities of provincially significant Upper Skeena coho and regionally significant summer run steelhead. Fish sampling upstream of the culvert has identified fish use by resident Dolly Varden and rainbow trout only. This sampling confirmed initial suspicions of the structure being a full barrier to anadromous fish passage in addition to restricting resident fish migration patterns. In the summer of 1999, the mainline road culvert was removed and an arch culvert was installed that re-established access to the upper reaches for the target populations of steelhead and coho.

Assessments and Prescriptions
The initial assessment of the Fenton Creek culvert was completed by Morris and Eccles (1975). The culvert was identified as a potential barrier to fish passage (Fig. 6-40). In 1999 Bustard (1998) identified the road structure as a barrier to fish passage due to the outlet drop and very fast water velocities that combine to stop fish passage for both coho and steelhead.

These assessments in addition to recommendations from the MELP and DFO) identified the Fenton Creek culvert as one of the highest priority restorative projects in the Morice Watershed as the habitats for targeted upper Skeena River coho and steelhead would be the primary beneficiary.

Rehabilitation Work
The wooden stave culvert on lower Fenton Creek was removed and replaced with a large arch culvert during a compressed two-week implementation schedule. The entire flow of Fenton Creek had to be rerouted around the deactivation and construction site for approximately 100 m upstream and downstream of the site for the construction period. Fish in the immediate project area were salvaged and placed downstream of the construction site. The arch culvert was placed on embedded concrete footings that allowed the natural stream bed to be re-established at the appropriate gradient (Figs. 6-41, 6-42).

Cost Summary

Labour and Equipment	$ 230,000
Materials	25,000
Total Cost	$255,000

Outputs
Access to over 7 km of spawning and rearing habitat was re-established.

Proposed Work
Both adult and juvenile fish were moving through the new structure in the fall of 1999 and both juvenile coho and steelhead have been sampled upstream of the arch culvert.

These findings suggest spawning and subsequent juvenile rearing in the upper reaches of Fenton Creek has been re–established. An ongoing routine monitoring program that will be completed annually to evaluate the long–term effectiveness of the structure.

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Figure 6–40. "Before" photo of 1960s constructed wooden stave culvert creating a full fish passage barrier on lower Fenton Creek.

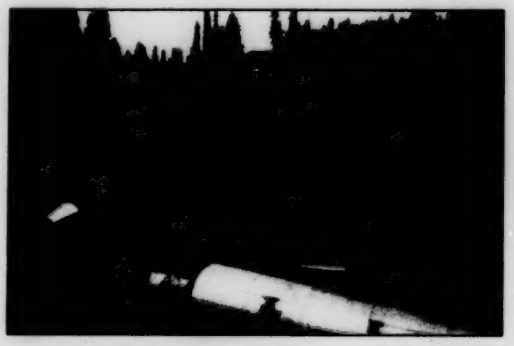
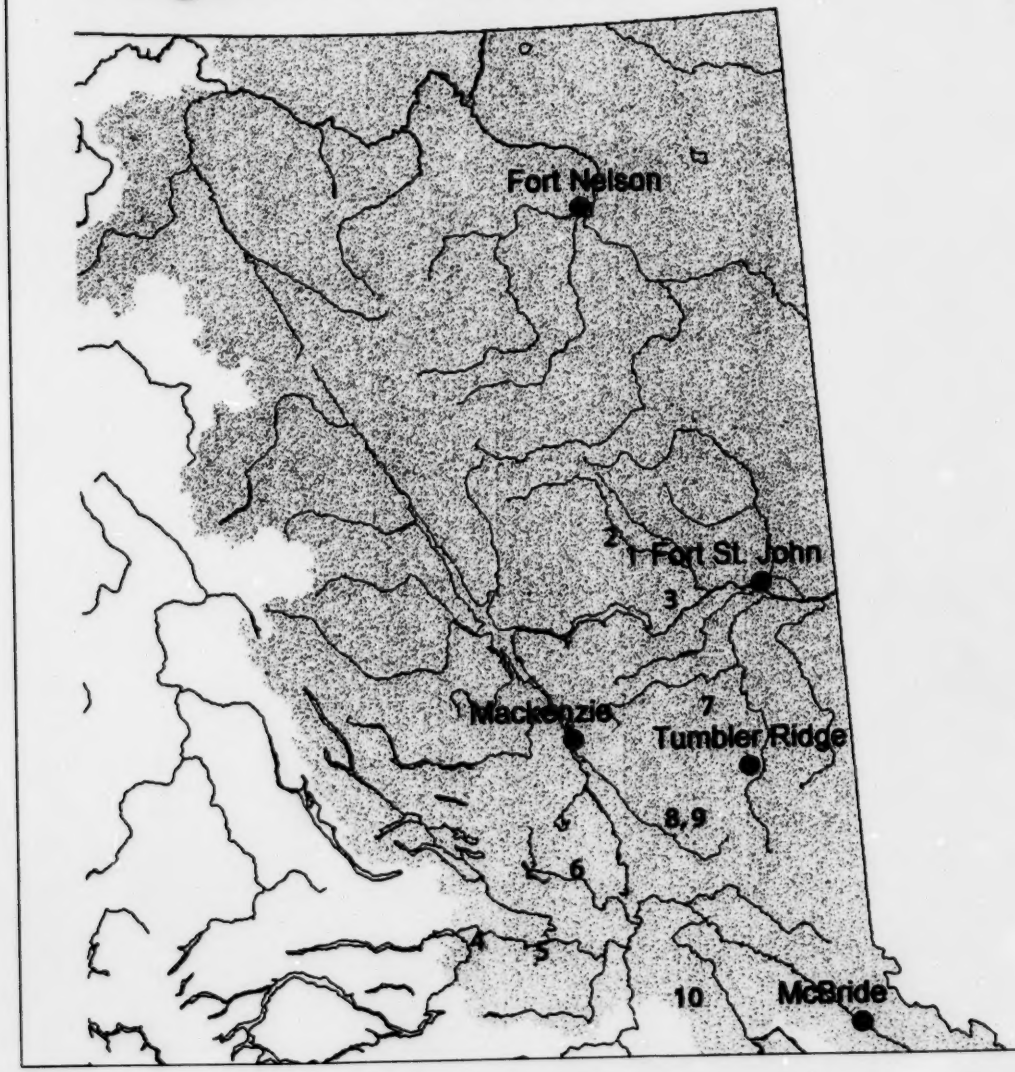


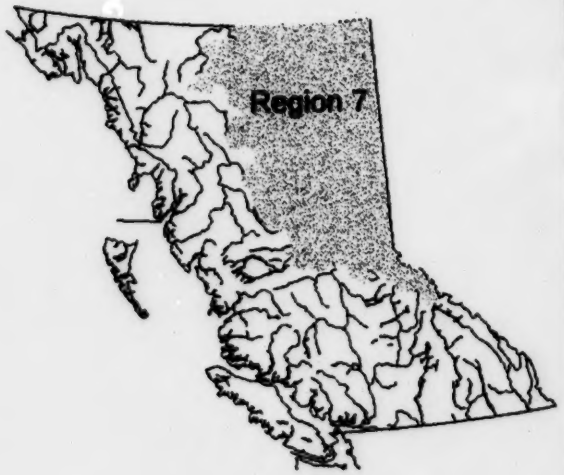
Figure 6–41. Placement of new arch culvert on concrete footings.

Figure 6–42. Arch culvert installed with flows re–established. The final construction stage was to replace road fill over the arch.

Omineca–Peace Region

Region 7. Omineca–Peace





WRP Projects

1	Colt Creek
2	Horseshoe Creek
3	Farrell Creek
4	Swanson Creek
5	Corkscrew Creek
6	Nahouli Creek
7	Martin Creek
8, 9	Table River
10	Narrowlake Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 7, Omineca–Peace.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
1	Omineca–Peace	Graham River	Colt Creek Instream and Riparian Restoration	10	6257963	540102	235–304300–06300	00000LHAF
2		Horseshoe Creek	Unnamed Tributary Fish Passage	10	6278562	532667	235–397800	00000UHAF
3		Peace River	Farrell Creek Tributary Fish Passage	10	6220128	578645	230–786200	00000UPCE
4		Nechako River	Swanson Creek Off–channel and Instream Restoration	10	5954795	385355	180–507600	00000CHES
5		Nulki–Tachick Lakes	Corkscrew Creek Restoration	10	5973076	442082	180–271000–56200	00000NECR
6		Sukunka River	Martin Creek Instream and Riparian Restoration	10	6150032	585514	234–443900–14100	00000PINE
7		Table River	Tributary 404 Fish Passage	10	6068039	558851	2630–450800–404	00000PARS
8		Table River	Tributary 427 Fish Passage and Instream Restoration	10	6069119	559031	2630–450800–427	00000PARS
9		Willow River	Narrowlake Creek Streambank Stabilization and Instream Restoration	10	5937121	561213	100–596500–43500	00000WILL

COLT CREEK INSTREAM AND RIPARIAN RESTORATION

Objectives
The objectives of the Colt Creek Restoration Project are to stabilize sections of stream where lateral migration was occurring and to improve local habitat conditions for fish through the creation of pools and increased cover.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Author
Brendan Anderson

Proponent/Implementing Partners
Peace Sub–Region, Ministry of Environment, Lands and Parks.

Watershed/Stream
Graham River/Colt Creek

Location
The Colt Creek Watershed is located roughly 115 km WNW of Fort St. John, BC. Restoration work took place in the upper third of the system on a 2.5–km section of mainstem beginning at the first ford crossing on Colt Creek Road and extending upstream.

Introduction
Colt Creek is a fourth–order tributary to the Graham River with a drainage area of 155 km^2. The system flows in a roughly west to east direction through both the Boreal White and Black Spruce and the Engelmann Spruce–Subalpine Fir Biogeoclimatic zones. The upper reaches of Colt Creek are typified by a sinuous channel pattern with riffle–cascade morphology and cool clear flows. Colt Creek is primarily a bull trout system with other salmonid species such as rainbow trout, Arctic grayling (*Thymallus arcticus*), and mountain whitefish making use of the lower reaches.

Forestry activity in the watershed began over 20 years ago; however, the majority of harvesting took place from 1984 to 1990. The major negative impact from logging is the Colt Creek Road, which shares the valley corridor with Colt Creek for a length of 6 km, eliminating large sections of riparian buffer.

Assessments and Prescriptions
A Level 1 Fish Habitat Assessment (FHAP) was completed on Colt Creek in 1997. The assessment identified hazard indices of greater than 0.5 for surface erosion and riparian buffers in three of the sub–basins. In particular, road construction and crossings were determined to be negatively affecting the system through the creation of large debris jams and severe erosion.

A Level 2 FHAP completed in 1998 on a 2.7–km section of Colt Creek identified an overall lack of pool habitat, limited spawning opportunities, and low LWD abundance (Westcott, 1998b).

Past Rehabilitation Work
Restoration work first began on Colt Creek in 1996. The restoration activities consisted largely of v–weirs developed at the ford crossings on Colt Creek Road, riprapping and tree revetment of unstable bank areas along the Colt Creek forest road, in–channel boulder placements, and brush layering. In 1999, assessments of these efforts found that while placing riprap successfully provided bank protection, several areas of the eroding streambank along the forest road remained unprotected. A 100–year flood event in 1996 had led to the failure of the tree revetment structures.

Rehabilitation Work
Instream rehabilitation work on Colt Creek took place over the course of 12 days beginning in late August. Restoration work completed in 1999 included the following:

- Development of seven large lateral debris catchers, called LT–52 (LGL 1999; Figs. 7–1 and 7–2). The structures were situated on the outside of meander bends to provide increased bank stability and maintain channel position where lateral migration or bank erosion was occurring.
- Development of seven riffle structures immediately downstream of the LT–52 structures to maintain pool depths upstream of the riffles and help direct flow downstream.
- Placement of single rootwads amidst existing riprap or downstream of previously constructed boulder weirs. The rootwads were placed to promote local scouring action and provide increased cover within pools.

- Planting of approximately 5000 shrubs along sections of bank or gravel bars where no woody vegetation existed. The shrubs will provide increased bank stability and reduce the delivery of sediment to the stream.

All instream construction and channel excavation was completed with a John Deere 792 DLC tracked excavator with thumb attachment. In total, approximately 200 trees with rootwads attached (white spruce *(Picea glauca)*; average dbh of 30 cm) and 140 m^3 of rock were brought to the site for use in construction. Additional rock was utilized from on–site.

Cost Summary

Labour	$37,800
Equipment and Materials	45,500
Total Cost	$83,300

Outputs

Restoration work was completed on 2.5 km of mainstem habitat.

Production Estimates

Based on production estimates of 0.16 bull trout per m^2 of restored mainstem (Koning and Keeley, 1997), the 2500 m length of Colt Creek should support a population of roughly 2,800 juvenile and adult bull trout per year.

Proposed Work

Further restoration work is still required on Colt Creek to help stabilize the channel activity and reduce sediment loading of the stream. Proposed work includes:

- Stabilizing remaining sections of channel where lateral migration or bank sloughing is occurring.
- Development of LWD wedges on point bars across from the LT–52 structures to ensure that stream flow is maintained against the outside of the meander bends.
- Addition of boulder clusters or installation of riffle–pool sequences on those sections of Colt Creek that have been channelized.
- Planting white spruce and cottonwoods to unvegetated bank tops and gravel bars, respectively.
- Willow staking of disturbed or newly formed streambanks.

For Further Information

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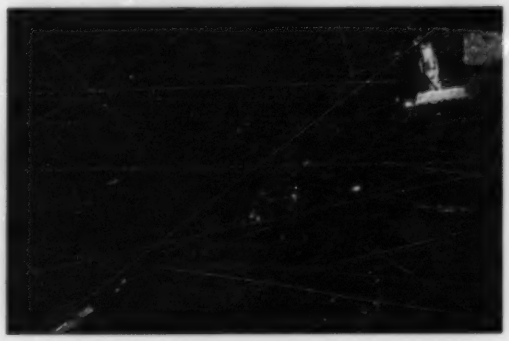

Figure 7–1. Construction of an LT–52 lateral debris catcher. During construction, streamflow is diverted around the area of work (visible at left) to reduce sedimentation.

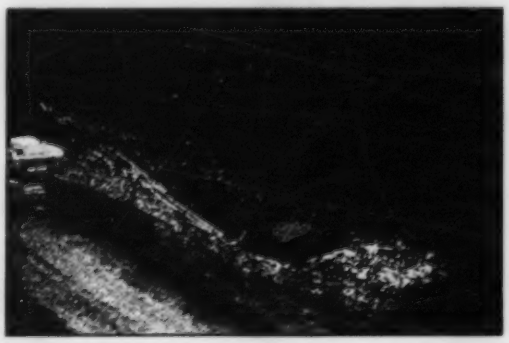

Figure 7–2. A completed LT–52 and riffle sequence. Residual pool depths of up to 90 cm will be maintained at this site.

STREAM CROSSING RESTORATION ON AN UNNAMED TRIBUTARY TO HORSESHOE CREEK

Objectives
This stream crossing required remediation to restore fish passage for juvenile bull trout to the upper reaches of the unnamed tributary to Horseshoe Creek.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Author
Brendan Anderson

Proponent/Implementing Partners
Fort St. John Division of Canadian Forest Products Ltd.

Watershed/Stream
Horseshoe Creek/Unnamed tributary to Horseshoe Creek

Location
The unnamed tributary flows into Horseshoe Creek from the southwest, roughly 120 km WNW of Fort St. John. The crossing is on Horseshoe Creek Road at km 10.1.

Introduction
The unnamed tributary is a second–order system with a catchment area of 9.3 km^2. Roughly 6.5 km of potential habitat (<30% gradient) exists above the crossing. The instantaneous Q100 for the stream was estimated to be 10.2 m^3/s.

Rocky Mountain foothill basins such as Horseshoe Creek provide important spawning and nursery areas for bull trout.

Assessments and Prescriptions
A fish–passage assessment was completed on the stream crossing in August 1998. Assessment methods were based on the Fish Passage—Culvert Inspection (FPCI) procedures developed by Michael Parker (1999). The stream was passing through a single 1650 mm round culvert (24 m length). The crossing was identified as a year–round barrier to juvenile passage and a probable barrier to adults during periods of high flow. This was based on measured flow velocities of 1.19 m^3/s, and an outfall drop of 9 cm. No substrate was present on the bed of the culvert. Fish sampling near the crossing confirmed the presence of bull trout as well as slimy sculpins. Stream habitat quality upstream of the crossing was rated as excellent for trout rearing and spawning.

An engineering assessment of the crossing prescribed culvert replacement with a multi–plate pipe arch culvert (4270 x 2210 mm; Fig. 7–3).

Rehabilitation Work
Installation of the multi–plate pipe arch culvert took place over the course of 10 days in August. A John Deere 792 DLC tracked excavator was used to remove the original culvert and install the multi–plate pipe arch culvert. Large riprap material was used to protect the footings (Fig. 7–4).

A temporary bridge was installed to allow for local road traffic.

Cost Summary

Labour	$15,000
Equipment and Materials	55,000
Total Cost	$70,000

Outputs
Access was restored to 6.5 km of stream habitat for juvenile bull trout.

Production Estimates
Based on production estimates of 0.16 bull trout per m^2 of restored mainstem (Koning and Keeley, 1997), the section of the unnamed tributary upstream of the road crossing should support a population of roughly 3100 juvenile and adult bull trout.

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Figure 7–3. Looking upstream at the outlet of the multi–plate pipe arch culvert following construction.

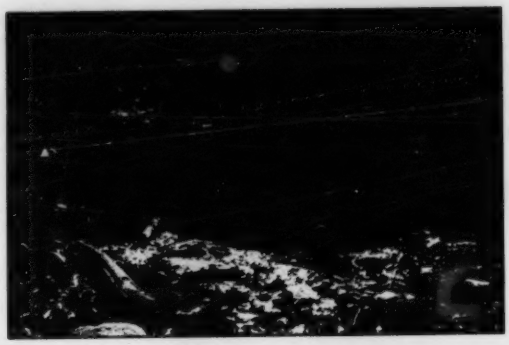

Figure 7–4. The streambed beneath the crossing was created using a range of substrate sizes. The streambed and footings are protected from scouring action while habitat complexity is maintained.

STREAM CROSSING RESTORATION ON AN UNNAMED TRIBUTARY TO FARRELL CREEK

Objectives
The objective of this project is to restore fish passage for juvenile rainbow trout to the upper reaches of the unnamed tributary.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Author
Brendan Anderson

Proponent/Implementing Partners
Fort St. John Division of Canadian Forest Products Ltd.

Watershed/Stream
Peace River/Unnamed tributary to Farrell Creek.

Location
The unnamed tributary flows into Farrell Creek from the south, roughly 70 km west of Fort St. John. The crossing is on Beryl Prairie Road 14.1 km from the junction with Kobes Creek Forest Service Road.

Introduction
The unnamed tributary is a second–order system with a catchment area of 11.7 km^2. Roughly 8.0 km of potential habitat (<30% gradient) exists above the crossing. The instantaneous Q100 for the stream is estimated to be 10.5 m^3/s.

Farrell Creek flows directly into the Peace River. The system supports populations of rainbow trout and Arctic grayling as well as a number of non–salmonids.

Assessments and Prescriptions
Based on the Fish Passage Culvert Inspection (FPCI) procedures developed by Michael Parker (1999), an assessment was completed on the culvert crossing in the summer of 1998. The stream was flowing through two round culverts (1000–mm diameter; Fig. 7–5). The crossing was identified as a year–round barrier to fish passage due to a combination of high flow velocities and culvert slopes, and an impassable outfall drop. The culverts were identified as undersized based on initial estimates of the Q100. Fish sampling near the crossing confirmed the presence of rainbow trout in the system as well as lake chub (*Couesius plumbeus) and* slimy sculpins.

An engineering assessment of the crossing prescribed culvert replacement with a single large culvert (2600 mm) set at stream grade and embedded by 20%.

Rehabilitation Work
Restoration of the culvert crossing took place over the course of 14 days in September. A John Deere 792 DLC tracked excavator was used to remove the original culverts and install the new one.

Once installation of the culvert was complete, material was placed through the length of the culvert to initiate substrate deposition (Fig. 7–6). Large material (D90 or greater) was set with a spacing of roughly 0.5 m along the culvert bed. Smaller material (gravel and fines) was then added to help cement the larger material in place.

A temporary bridge was used to allow for local road traffic.

Cost Summary

Labour	$15,000
Equipment and Materials	43,000
Total Cost	$58,000

Outputs
Access was restored to 8.0 km of stream habitat for rainbow trout, Arctic grayling, and other non–salmonids.

Production Estimates
Little information exists on the production estimates of Arctic grayling or the effect of interspecific interactions between rainbow trout and Arctic grayling. However, based on production estimates of 0.097 rainbow trout per m^2 of restored mainstem (Koning and Keeley ,1997), the section of the unnamed tributary upstream of the road crossing could be expected to support a mixed population of roughly 1500 juvenile and adult salmonids.

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Figure 7–5. Pre–construction view of the stream crossing outlet. All flow is passing through the culvert at left where an outfall drop of 31 cm falls directly onto rocks.

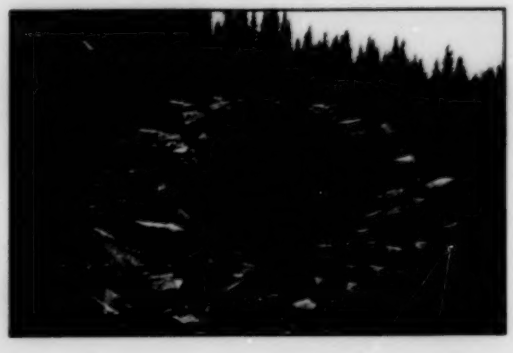

Figure 7–6. Post–construction view of the crossing outlet. Material has been placed through the length of the culvert to initiate substrate deposition.

SWANSON CREEK OFF–CHANNEL AND INSTREAM RESTORATION

Objectives
To increase/develop off–channel rearing and spawning habitat and to restore mainstem channel habitat conditions.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Authors
W.O. Rublee, ARC Environmental and A.C. Mitchell, Triton Environmental

Proponent/Implementing Partners
Ministry of Environment Lands and Parks, Omineca sub–region.

Watershed/Stream
Nechako River/Swanson Creek

Location
Sites are located at 1.3, 2.8 and 3.3 km upstream of the confluence with the Nechako River. Access is by Kenney Dam Rd. at approximately km 68.

Introduction
Following a FHAP of tributaries of the Nechako River in 1997, the site was identified as a good candidate for restoration activities in order restore fish habitat values and in part to reverse channel degradation caused by a 1993 rain event in the upper Nechako Valley.

Assessments and Prescriptions
Original assessments determined that rainbow trout production is limited in Nechako River tributary systems. Prescriptions for habitat restoration included the development of two side channels to provide rearing habitat (specifically until channel conditions in the mainstem recovered) and mainstem structures for channel stability.

Rehabilitation Work
Lower Site: An existing groundwater–fed channel/pond area, which was inaccessible to fish, was deepened and widened using an excavator to increase rearing habitat area and volume (Figs. 7–7 and 7–8). The existing head ponds were deepened and cleaned of accumulated organic materials. A new exit/entrance to the channel was excavated to provide access for juvenile trout and salmon. In order to protect the side channel, a setback dyke was constructed along the right bank of the mainstem upstream of the side channel. LWD was placed in the channel to provide refugia for rearing salmonid juveniles.

Upper Site: An abandoned side channel was excavated and pools and riffles, as well as habitat complexes, were constructed to provide habitat and control local water elevations and velocities (Fig. 7–9). The head pond was excavated to a lower elevation to intercept additional groundwater.

Mainstem: Large woody debris and structures were placed in the mainstem, mainly along the left margin, and selected portions of the armour layer on one riffle were removed to ensure the channel down cuts and maintains its current course (Fig. 7–10).

Cost Summary

Supervision	$13,745
Equipment	9,027
Materials	1,626
Labour	584
Total Cost	$24,982

Outputs
Lower Site: 125 m in length, pond length approximately 70 m – 5 m in width (350 m^2) and 55 m of channel – 1 m width (55 m^2).

Upper Site: 207 m in length and averaging approximately 1 m in width (207 m^2).

Mainstem: 0.3 km and 180 m^2 of stream work.

Production Estimates

Lower Channel: Based on rearing density estimates of 1 chinook/rainbow trout per m^2 (Koning and Keeley, 1997), approximately 400 chinook/rainbow smolt/parr.

Upper Channel: Based on rearing density estimates of 1 chinook/rainbow trout per m^2 (Koning and Keeley, 1997), approximately 200 chinook/rainbow smolt/parr.

Immediate value of the off-channel habitats is to offset production loss in the mainstem until recovery can take place.

Habitat Structures: Production gains will be a result of structures accelerating the channel downcutting leading to the restoration of channel stability and complexity in the lower 3 km of Swanson Creek.

Proposed Work

Deepening of a side channel on the lower site to increase overwintering potential and additional habitat complexing in mainstem to provide channel stability and fish habitat

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Figure 7-7. Outlet of lower side channel.

Figure 7-8. Lower section of upper side channel after complexing.

Figure 7-9. Logjam on mainstem.

Figure 7-10. Rootwads on mainstem.

NULKI–TACHICK WATERSHED RESTORATION PROJECT

Objectives

The three main objectives of the Nulki–Tachick Watershed Restoration Project (NTWRP) in 1999 were to:

- restore logged riparian areas by planting a mixture of hybrid spruce (white/Englemann), low–level willow, black cottonwood and mountain alder;
- restore stream habitat at selected areas in order to aid the natural recovery of the local rainbow trout fishery;
- document baseline habitat use by monitoring changes in total fish biomass, abundance, and age class structure as indicators of the effectiveness of restoration efforts.

FRBC Region/MELP Region/MOF Region

Omineca–Peace/Omineca–Peace/Prince George

Authors

Scott McIntosh and Cam Irvine

Proponent/Implementing Partners

Saik'uz First Nation

Watershed/Stream

Nulki–Tachick Lakes/Corkscrew Creek

Location

The Nulki–Tachick Lake Watershed is located in British Columbia's central interior, 100 km west of the City of Prince George, and 20 km southwest of the District of Vanderhoof. Corkscrew Creek is a fourth–order stream on the south side of Nulki Lake, approximately 8 km southwest of Vanderhoof. Stoney Creek is the principal outlet stream of Nulki Lake and the principal inlet stream to Tachick Lake, flowing north for 6.4 km.

Introduction

The Nulki–Tachick Watershed lies within the sub–boreal spruce biogeoclimatic zone. Approximately 35–50% of the watershed has been cleared by agricultural and forest industries since the 1950s with major developments in the headwaters prior to implementation of the Forest Practices Code. Much of the Corkscrew Creek mainstem and tributary riparian zone forest (approx. 35 km) has been harvested; therefore recruitment sources for LWD have been removed. Subsequent losses of instream LWD and pool habitat has been detrimental to juvenile rearing habitat.

The Nulki–Tachick Watershed hosts diverse fish species including mountain whitefish, burbot, northern squawfish, peamouth chub, lake chub, redside shiner, longnose sucker, largescale sucker and prickly sculpin. This natural resource provides an important sport fishery to residents of the Vanderhoof and Prince George areas and contributes to a sustenance fishery for the people of the Saik'uz First Nation.

The focus over the five–year duration (1995–2000) of this project has specifically been on rainbow trout. Corkscrew Creek boasts a 60–km network of stream created by a 2–m waterfall located 2 km from its confluence with Nulki Lake. Only rainbow trout are able to negotiate these falls and access the extensive habitat above.

Assessments and Prescriptions

An IWAP, a Level 2 Fish Population and Riverine Habitat Assessment, a Water Quality Study and a Fisheries Investigation contributed data that directed the development of the 1999 project objectives.

The 1995–1998 fisheries investigations and population assessments in Corkscrew Creek offer an accumulation of aging data that indicate rainbow parr over–winter in this system for one to three years before taking up residence in the lakes downstream. The lack of LWD and unstable banks void of riparian vegetation are eroding and embedding spawning gravel in the lower reaches of Corkscrew Creek. These factors are likely contributing to poor juvenile survival and low rainbow trout recruitment to Nulki Lake and Tachick Lake.

Rehabilitation Work

In 1999, the Saik'uz First Nation and Conor Pacific Environmental Technologies Inc. focused efforts on watershed restoration by conducting:

- instream restoration using LWD to provide velocity breaks and complex habitat for juvenile rainbow trout (Fig. 7–11);
- removal of an old logging bridge on Corkscrew Creek (R–5) near the Corkscrew 200 Road;
- restoration of riparian areas by improving bank stabilization structures and planting woody species to stabilize banks, provide cover, and future recruitment of LWD;

- fencing at a sensitive portion of Corkscrew Creek to reduce livestock degradation of banks in the Johnson's Meadow area (R–4);
- monitoring of discharge and temperature in both creeks; juvenile rainbow trout migration from Corkscrew Creek to Nulki Lake and fish using electrofishing surveys.

Overall, 109 pieces of large woody debris and 261 boulders in 27 structures were added. Increases in LWD counts in restored reaches varied from poor to good (Johnston and Slaney, 1996). The structures were designed after Cederholm *et al.* (1997) and natural templates. Boulder and LWD placement in structure assemblage was achieved using two teams of Belgian draft horses owned and driven by Matt Jonke of Nechako Valley Horse Logging (Fig. 7–12). The Hilti–epoxy method (Fontaine and Merritt, 1988) was used to anchor boulders to LWD in the structures.

Cost Summary

Project Management and Design	$11,890
Engineering	5,670
Construction (teamster and horses)	10,800
Material Transport (trucks)	3,885
Labour and Expendable Field Equipment	11,085
Total Cost	$43,330

Outputs

From eight to 30 pieces of LWD per 100 m were added overall to approximately 460 m of creek. In R–5 of Corkscrew Creek, 160 m of streambank were stabilized at 16 sites.

Proposed Work

The growth and stability of bank stabilization works using bioengineering techniques will be assessed in 2000. In addition, the 1998 and 1999 LWD placements will be monitored to determine rainbow trout use and pool depth in relation to pre–restoration conditions.

For Further Information

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Figure 7–11. LWD structure designed to increase pool depth, provide cover and velocity break.

Figure 7–12. Transporting LWD via riparian cart.

MARTIN CREEK INSTREAM AND RIPARIAN RESTORATION

Objectives
The objectives were to stabilize the channel position through the restoration section of Martin Creek and improve local habitat conditions through the creation of pools and increased cover.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Author
Brendan Anderson

Proponent/Implementing Partners
Peace Sub–Region, Ministry of Environment, Lands and Parks.

Watershed/Stream
Sukunka River/Martin Creek

Location
The Martin Creek Watershed is located roughly 20 km south of Chetwynd, BC. Restoration work took place on two sections of stream. A 1–km section of stream beginning 200 m downstream of the Sukunka Forest Service Road (FSR) bridge and extending upstream (Reach 1) was one site. The other was a 1–km section of stream beginning roughly 1 km upstream of the Sukunka FSR bridge crossing (Reaches 2 and 3).

Introduction
Martin Creek is a fourth–order tributary to the Sukunka River with a drainage area of 110 km^2. The system flows in a roughly SSW to NNE direction through the Boreal White and Black Spruce Biogeoclimatic zone. Fish distribution is limited to the lower 4.5 km of mainstem due to a series of impassable falls. Martin Creek is noted for its importance as a historic Arctic grayling spawning and rearing channel in the lower Sukunka River basin (Stuart and Chislett, 1979). Other salmonid species utilizing Martin Creek include rainbow trout, bull trout, and mountain whitefish.

Over the last 30 to 40 years road development, logging in the headwaters, areas of channelization and agricultural land clearing have led to increased sediment loading and flow fluctuations.

Assessments and Prescriptions
A Level 1 Fish Habitat Assessment (FHAP) was completed on Martin Creek in 1997. The lower reaches of Martin Creek were severely aggraded, with simplified habitat conditions, a high channel width:depth ratio (18:1), areas of channel braiding, and an over–widened valley floor created by numerous avulsions and lateral migration.

In 1998, LGL Limited made an on–site assessment of Reaches 2 and 3. Based on this assessment and the Level 1 FHAP, restoration prescriptions were developed by LGL for implementation in 1999.

Part of the prescriptions for Reaches 2 and 3 called for the development of "LT–52" structures. Essentially large lateral debris–catchers, the structures are designed to promote bank and channel stability while creating scouring action to maintain pools (Fig. 7–13).

Past Rehabilitation Work
In 1998, restoration work was completed by MELP on Reach 1 of Martin Creek. Restoration work included the development of eight riffle–pools, 14 low profile LWD structures, and the excavation of a side channel to groundwater levels. Further restoration work was completed on this reach in 1999.

Rehabilitation Work
Rehabilitation work on Martin Creek took place over the course of 12 days beginning in July and ending in August.

Reach 1
1999 restoration work on Reach 1 included the following:

- Development of five low–profile triangular LWD structures located downstream of the previously constructed riffles (Fig. 7–14).
- Addition of seven floating LWD structures to the small side channel pools.
- Willow staking and application of willow bundles on unstable banks or newly constructed banks.
- Planting of 2000 cottonwood seedlings (1+0) on floodplain areas and constructed berms.

Reaches 2 and 3

Restoration works completed on Reaches 2 and 3 include the following:

- Development of eight LT–52 structures (Fig. 7–13). The structures were situated on both the outside of meander bends to provide increased bank stability and maintain channel position, and spanning historic channels (now dewatered) to confine flows to the contemporary channel.
- Development of nine riffle structures immediately downstream of the LT–52 structures to maintain pool depths upstream of the riffle and help direct flow downstream.
- Development of six low profile triangular LWD structures to provide bank protection and increased habitat complexity.
- Willow staking and application of willow bundles to newly created or disturbed banks.

All instream construction and channel excavation was completed with a Hitachi EX200 excavator with thumb attachment. In total, approximately 275 trees with rootwads attached (average dbh of 30 cm) and 320 m^3 of rock were brought to the site for use in construction. Additional rock was utilized from on–site.

Cost Summary

Labour	$32,400
Equipment and Materials	68,000
Total Cost	$100,400

Outputs

Restoration work was completed on 2.0 km of mainstem habitat.

Production Estimates

Little information exists on the production estimates of Arctic grayling or the effect of interspecific interactions between grayling, and other salmonids. However, based on production estimates of 0.097 rainbow trout per m^2 of restored mainstem (Koning and Keeley, 1997), the 2 km of mainstem rehabilitated in 1998 and 1999 could be expected to support a mixed population of roughly 3,100 juvenile and adult salmonids.

Proposed Work

Further bioengineering work will be completed on Reaches 2 and 3 next year to increase bank stability and reduce sedimentation.

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Figure 7–13. Completed LT–52 structure (at left). A residual pool depth of 90–110 cm is maintained here by scouring action around the rootwads.

Figure 7–14. Triangular LWD structure developed downstream of a constructed riffle. The LWD structure will lengthen the pool area and provide cover for fish.

TABLE RIVER STREAMBANK STABILIZATION AND INSTREAM RESTORATION

Objectives
The objectives of the Table River Watershed restoration activities during 1999 were to increase fish habitat and water quality by reducing sediment input into selected tributaries where road crossings have failed.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Authors
Ray Pillipow, Andrew Wilson and John McInnis

Proponent/Implementing Partners
Ministry of Environment, Lands and Parks.

Watershed/Stream
Table River/Unnamed tributaries 404 and 293

Location
Restoration sites along the Table River Watershed are located approximately 132 km North of Prince George. Travel north on Hwy. 97 for 75 km, turn right onto the Tacheeda FSR to the Parsnip River. Follow the Table River to kilometre 1034 for tributary 427, turn right at km 1032, cross the Table River, turn right and follow narrow road to tributary 404.

Introduction
The Table River Watershed drains 506 km^2. Logging activity during the 1980s has resulted in 40% of the valley bottom being logged to the stream banks (Mathias *et al.*, 1998). The watershed was further affected in the 1980s by the construction of the Tumbler Ridge rail extension. These activities are thought to be responsible for increased erosion and a decrease in fish habitat. Game species that reside within the Table River include rainbow trout, bull trout, Arctic grayling and Rocky Mountain whitefish.

Assessments and Prescriptions
Previous assessments by PWCP (Peace Williston Compensation Program) were reviewed by WRP and were beyond the budget constraints for 1999, therefore tributary stream crossings were focused upon. Prescription development for crossing rehabilitation was developed by R. Pillipow and A. Wilson.

On tributaries 293, 404 and 427, Level 2 prescriptions were developed for future restoration activities.

Rehabilitation Work
Restoration work was focused upon the rehabilitation of crossings at tributaries 404 and 427. Timber bridges had collapsed resulting in an increase of point source sediment to the streams, a disruption of hydrologic processes, as well as local aggradation and decreased channel stability downstream. Bridge material was removed from each site, the stream banks were re–contoured to a natural repose, and the bridge material was placed along the banks in a down slope chevron pattern to reduce erosion from overland flow and create micro habitat for vegetative regeneration (Figs. 7–15 and 7–16). Each site was seeded with grass mixtures and, where applicable, conifer seedlings removed from banks were replanted upon completion of work. Triangular LWD structures were constructed at the crossing of tributary 427 to increase fish habitat and to reduce bank erosion.

Cost Summary

Materials	$ 8,462
Labour	34,000
Equipment	30,035
Total Cost	$72,497

*All boulders and wood were provided to the project at no cost.

Outputs
Tributary 427: 0.1 km (130 m^3 of road fill) of streambank restored.
Tributary 404: 0.03 km (16 m^3 of road fill) of streambank restored.

Production Estimates
Increased habitat quality and channel stability will result from work completed at the crossings. Increases in production are expected to be marginal initially, increasing with stability of the stream channels.

Proposed Work

Level 2 FHAP was conducted on three (3) tributaries during the autumn of 1999. Prescription development was focused on creating fish habitat and reducing bank erosion through the application of LWD and riffle construction techniques.

For Further Information

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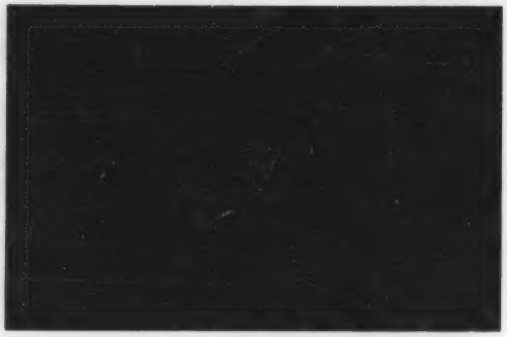

Figure 7–15. Aerial view of bridge material in chevron formation.

Figure 7–16. Used bridge material placed to aid in erosion control and vegetation establishment.

NARROWLAKE CREEK STREAMBANK STABILIZATION AND RESTORATION DEMONSTRATION SITE PROJECT

Objectives
The objectives of 1999 restoration activities along Narrowlake Creek were to stabilize areas of accelerated erosion along three streambanks, reducing sediment delivery to the stream channel and to re–create fish habitat as a result of restoration treatments.

FRBC Region/MELP Region/MOF Region
Omineca–Peace/Omineca–Peace/Prince George

Authors
Ray Pillipow, Andrew Wilson and John McInnis

Proponent/Implementing Partners
Ministry of Environment, Lands and Parks.

Watershed/Stream
Willow River/Narrowlake Creek

Location
Narrowlake Creek is located approximately 80 km southeast of Prince George, and is accessed from the Willow 100 Forest Service Road at km 169.5.

Introduction
Narrowlake Creek is a fifth–order stream with a drainage area of 187 km^2. From 1966 to 1974, a total of 35% of the basin was logged, of which, 80% occurs along the valley bottoms resulting in over–widened channels and reduced fish habitat. Game fish found within Narrowlake Creek include, bull trout, rainbow trout, Rocky Mountain whitefish, and chinook salmon.

Assessments and Prescriptions
During 1999, prescriptions were developed (LWD catchers) for treatment reach 3 by Rheal Finnigan. Streambank protection along treatment reach 2 was designed and completed by Andrew Wilson.

Assessments in 1999 included two–pin triangulation measurements of existing structures (Slaney *et al.*, 1997) to determine structural stability, snorkel counts around structures along treatment reach 2 to determine utilization by fish, and ballast assessments of LWD structures as per D'Aoust (1998).

Rehabilitation Work
Narrowlake Creek restoration work occurred along treatment reaches 2 and 3. Treatment reach 2 restoration activities consisted of the completion of bank revetments located at 0+340 m. This location is characterized by a 150 m long eroding bank of unconsolidated alluvial gravel with a mid–horizon clay seam near the downstream end of the bend. The clay seam has resulted in small–scale mass wasting, creating a tight radius of curvature, and accelerated erosion. Treatment of this eroding bank was initiated in 1998 with the construction of a 125 m LWD and boulder revetment. Additional LWD and boulders were added to this revetment in 1999 to provide additional habitat features and further protect the eroding bank. The downstream most 25 m was not restored in 1998.

In 1999, a 25 m x 7 m lateral LWD jam was constructed in this area. This jam was installed to prevent further erosion of the downstream margin of the bank, and increase the amount of LWD cover in this section of Narrowlake Creek.

Adjustments were made to previously built structures along treatment reach 2 in efforts to increase functionality and/or to increase long–term stability. Planting with red osier dogwood, black cottonwood, and willow occurred at bar stabilization structures installed in previous years and at areas along the revetment built in 1998 where in–filling has occurred.

Along treatment reach 3, four debris catchers were designed and constructed by Rheal Finnigan. Placement of the structures were located at areas of excessive erosion along outside bends at 0+950 m and 1+130 m, respectively. The areas of bank erosion were similar to those of treatment reach 2: vertical banks of unconsolidated alluvial sand and gravel. The debris catcher structures consisted of 24 pieces of bucked LWD constructed and placed in such a fashion as to allow drifting LWD to collect upon the structures, creating a LWD jam, deflecting flow from the eroding banks and creating fish habitat by providing overhead cover and localized scour. Boulders were cabled together and draped over the debris catcher structures as ballast. Structures were built in tandem and placed four times their projection into the stream channel apart.

Cost Summary

Labour	$ 65,805
Equipment and Materials	54,762
Total Cost	$120,567

Outputs

0.4 km of streambank was restored along treatment reach 2.
0.4 km of streambank was treated along treatment reach 3.

Production Estimates

Year 3 focuses on the construction of fish habitat structures and completing work on eroding banks initiated in 1998. Fish population increases are expected with the increase in habitat from overhead cover and localized scour.

Proposed Work

Future work will consist of similar treatments in areas of excessive erosion or reduced habitat.

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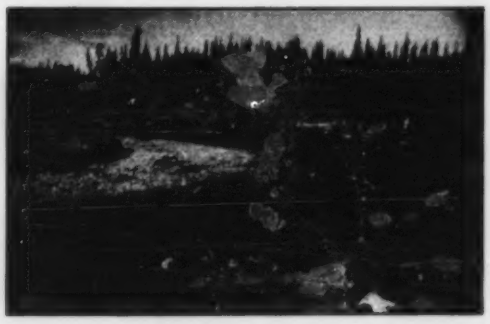

Figure 7–17. Whole tree revetment to protect eroding bank. Logjam added to increase habitat complexity.

Figure 7–18. First of two Finnigan debris catchers. Woody debris is naturally accumulating.

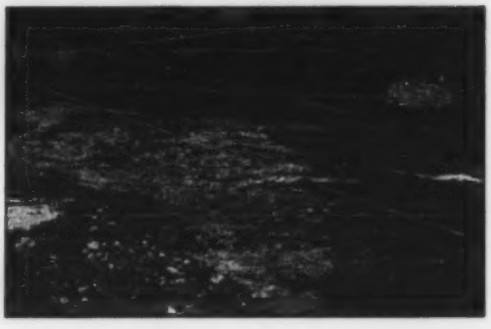

Figure 7–19. Second of two Finnigan debris catchers. Deposition zone formed on the right bank between the two ramps.

Late Submissions

VENNER CREEK WETLAND CULVERT DROP

Objectives
The Venner Creek Wetland Culvert Drop attempts to restore rainbow trout access to fair off–channel and excellent rearing habitat in reach 2 of Venner Creek by removing man–made barriers to upstream migration. The objective is to restore access to all life stages of rainbow trout.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Authors
Stephen Jones, R.P.F., Southern Interior Forestcraft Ltd., Consultant to Weyerhaeuser

Proponent/Implementing Partners
Weyerhaeuser Company Limited, Okanagan Falls Unit.

Watershed/Stream
Okanagan Basin, Vaseux Creek Watershed, Venner Creek sub–basin

Location
The site is located approximately 15–km southeast of Penticton near Okanagan Falls, BC. From 0 km on R201 (behind the Okanagan Falls sawmill), travel to 12.5 km, turn right onto R200, travel to 20 km, site occurs at the junction of R200 and Venner Road (left).

Introduction
On the east side of Okanagan Valley, Vaseux's seven sub–basins (Vaseux, Dutton, Underdown, Solco, Venner, McIntyre and Wabash) drain 292 km^2 of the Okanagan Highlands region. The watershed rises from 325–m elevation at the confluence with the Okanagan River to 2335 m at the peak of Baldy Mountain.

Trumbley *et al.* 1997, identified two man–made upstream migration barriers in reach two of the Venner Creek sub–basin. Both barriers were located on the main haul road R200 and clearly prevented upstream migration of fish due to perched outlets (Fig. 8–1). Several hectares of fair off–channel habitat and at least 100 m of excellent rearing habitat were available upstream in the wetland known as Venner meadows.

Assessments and Prescriptions
Summit Environmental Consultants Ltd. was retained to prepare on–site prescriptions for eliminating culvert outfall drops. Approved prescriptions utilized notched log cribs with plunge pools to eliminate the outfall drop and make the culverts passable for juvenile rainbow trout.

Rehabilitation Work
The pre–work meeting, site planning, delivery of unsorted angular riprap and riprap sorting took place during day one.

With approval from Ministry of Environment, Lands and Parks to work instream, crib log preparation, crib/plunge pool excavation, placement, armoring and anchoring of three log cribs was completed in day two. Logs were embedded in the stream bank at 2–m intervals from culvert outlets and were anchored with large (0.5–1.0 m) riprap. A four–inch trash pump equipped with a fish–friendly intake hose (covered with fine wire mesh) was used to dewater the work site. Discharging pumped water onto a large rock in the channel prevented downstream scour of the streambed. Critical instream work was completed in day 2 so that it was environmentally safe to re–introduce streamflow.

Logs were notched on day 3 after stream banks had re–wetted, plunge pools had filled and streamflow had re–established.

Cost Summary

Prescriptions	$1,166
Equipment and Labour	2,639
Rentals (pumps, misc. tools)	295
Total Cost	$4,120

Outputs
Two culvert barriers identified in Vaseux Creek Watershed Fisheries Habitat Assessment Procedure (Trumbley *et al.*, 1997) were mitigated (Fig. 8–2). The construction of step pools at two culvert outlets will enable all life stages of rainbow trout to access several hectares of off–channel habitat and at least 100 m of main channel habitat.

Production Estimates

Production estimates are not available however, after day 2 approximately 92 juvenile trout had accumulated in the lowermost plunge pool. It was apparent that fish were rapidly exploiting the improved access provided by log weir installation. These fish were retrieved with a bucket and relocated above the work site 20 m away. After notching the log weirs, several juveniles were observed swimming upstream through the weirs and culvert into the wetland.

Proposed Work

Ongoing effectiveness monitoring is proposed. All structures performed well during 2000 spring freshet and are frequently observed by forestry workers.

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Figure 8–1. An upstream view of culvert barrier prior to restoration. Note that the 30–40 cm outfall drop prevented passage of all rainbow trout life stages. Another outlet step pool was required for culvert pictured at the bottom of photo.

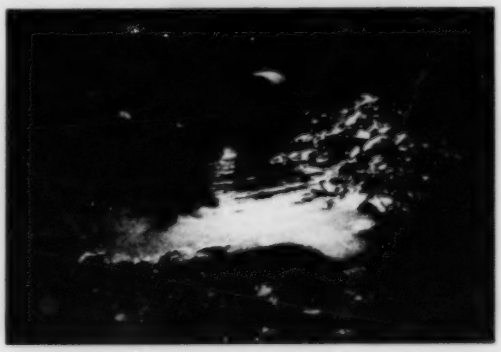

Figure 8–2. Upstream view of completed works. Outlet water level is higher and the culvert is now passable by all life stages.

VENNER CREEK LANDSLIDE REHABILITATION

Objectives
This project involved slope stabilization and erosion control to minimize sediment delivery to a fish bearing reach of Venner Creek.

FRBC Region/MELP Region
Thompson–Okanagan/Southern Interior/Kamloops.

Authors
Stephen Jones, R.P.F., Southern Interior Forestcraft Ltd., Consultant to Weyerhaeuser.

Proponent/Implementing Partners
Weyerhaeuser Company Limited, Okanagan Falls Unit.

Watershed/Stream
Okanagan Basin, Vaseux Creek Watershed, Venner Creek sub–basin

Location
The site is approximately 15–km southeast of Penticton near Okanagan Falls, BC. From 0 km on R201 (behind the Okanagan Falls sawmill), travel to 12.5 km, turn right onto R200, travel to 23.5 km, turn right onto spur road, drive ±100 m. Park at cabin and walk/quad 650–m on old trail to landslide.

Introduction
On the east side of Okanagan Valley, Vaseux's seven sub–basins (Vaseux, Dutton, Underdown, Solco, Venner, McIntyre and Wabash) drain 292 km^2 of the Okanagan Highlands region. The watershed rises from 325–m elevation at the confluence with the Okanagan River to 2335 m at the peak of Baldy Mountain. The landslide is within the Venner Creek sub–basin on southeastern aspect and is accessible by foot or ATV. The slide is ±0.35 ha in size.

Assessments and Prescriptions
Surficial materials in the landslide area are gravely glaciofluvial deposits on 60% slopes underlain by undifferentiated sands and cobbles. The terrain polygon is classed as potentially unstable. Upslope harvest on a glaciofluvial terrace in 1991 may have influenced landslide initiation. A spring near the head scarp, which is thought to be the initiation point, has created a significant drainage channel in unstable sand. Sediment is generated when the spring flows during breakup and heavy rainfalls. Most landslide debris (whole trees and parent material) was deposited in Venner Creek and has formed a large debris jam. Investigators believe the debris jam is stable and passable to rainbow trout during freshet so its removal was deemed unnecessary.

Prescriptions to stabilize the landslide were completed in summer of 1999 by Dobson Engineering Ltd. and implemented in fall of 1999.

Rehabilitation Work
Dangerous trees were felled prior to initiating rehabilitation work and a pre–work meeting was held with the crew to ensure people worked across the slope instead of below one another.

The 20–m long, 1–m high headscarp was removed by hand with shovels and picks. The initiation zone was stabilized with modified brush layers made from on–site logs and upland willow. Rebar was used to anchor sill logs.

Willow pole drains were constructed in nearby Venner meadows and flown by helicopter to the site 1.5 km away. Pole drains were installed in ±200 m of eroding drainage channels and were pinned to the slope with rebar stakes. A handcrew then backfilled the pole drains using shovels.

Live gully breaks were installed where on–site materials and slope conditions permitted. Logs and upland willow were used to form modified brush layers.

Although severely compacted, the deposition zone was planted with willow cuttings. The entire landslide was then heavily grass seeded to prevent surface erosion.

In spring 2000, the entire site was planted with 2055 Lodgepole pine seedlings, each with a fertilizer packet (teabags). Planted at the equivalent of about 6000 trees per hectare, the tree roots will rapidly colonize surficial materials and anchor them to the slope.

Fall 2000 effectiveness monitoring indicated:
- reduced surface erosion;
- 70% + grass cover;

- poor to acceptable survival of modified brush layers, gully breaks and live pole drains (improved performance and %CC of willow is anticipated);
- several buried modified brush layers near the initiation zone (beside road at top). Burial was due to downhill movement of loose sand from periodic cattle activity;
- poor willow survival in the deposition zone due to poor rooting zone aeration;
- 90% + survival of Lodgepole pine trees;
- 50–300% increase in Lodgepole pine height after one growing season;

Due to its favourable drought tolerance and adaptation to poor nutrient availability, Lodgepole pine is a recommended alternative species for bioengineering on steep, warm aspects in the ESSF and MS biogeoclimatic zones.

Cost Summary

Prescriptions	$ 1,166
Supervision	80
Equipment and Labour	7,360
Materials	317
Rentals (pumps, misc. tools)	52
Miscellaneous (helicopter)	1,043
Total Cost	$10,018

Outputs

Reduced erosion and sediment delivery to a known fish bearing reach of Venner Creek.

Production Estimates

The handcrew expended 32.4 person–days working on the 0.35 ha landslide. Major activities were willow harvesting, pole drain construction, installation of bioengineering and grass seeding. Planting of trees took 2 person–days for a total of approximately 35 person–days of labour.

Proposed Work

Effectiveness monitoring will continue in 2001.

For Further Information

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Figure 8–3. Crew installing live pole drains made of willow bundles.

DENNIS CREEK DEBRIS JAM REMOVAL

Objectives
The objective of this project was to remove a debris jam from the lower reach of Dennis Creek to prevent water quality and fish habitat degradation.

Dennis Creek is a sub–basin of the Penticton Community Watershed.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Authors
Stephen Jones, R.P.F. Southern Interior Forestcraft Ltd., Consultant to Weyerhaeuser

Proponent/Implementing Partners
Weyerhaeuser Company Limited, Okanagan Falls Unit.

Watershed/Stream
The work site is located within the Dennis Creek sub–basin of Penticton Creek Community Watershed (Okanagan Basin). The ±1.5 m high debris jam was located between the confluence with Penticton Creek (210 m downstream) and the crossing of Road 117 (10 m upstream).

Location
Site is approximately 15 km northeast of Penticton, BC. From 0 km on R201 (behind the Okanagan Falls sawmill), travel to 56.5 km on R201. Turn left on to Greyback Road and travel to Lower Dennis Road at 70 km. Turn left onto Lower Dennis Creek. Park here and walk downhill 380 m to the crossing of Road 117 and Dennis Creek.

Introduction
The debris jam originated from an adjacent slope failure (0.1 ha) which pushed the toe of the slope into the creek and below the existing Road 117. The failure infilled the creek and created a 1.5 m high debris jam (Fig. 8–4) that prevented upstream rainbow trout migration. Planned, large scale harvesting of spruce bark beetle infested timber was anticipated to potentially cause an increase in peak streamflows to the debris jam. Concerned that increased peak flows would dislodge the debris jam and degrade water quality and rainbow trout habitat, Ministry of Forests watershed specialists urged the removal of the jam prior to the 2000 freshet.

Assessments and Prescriptions
Previously unidentified, this site was discovered by watershed specialists making channel measurements of Dennis Creek. Once discovered, prescriptions to remove the debris jam and stabilize the channel were completed by Dobson Engineering Ltd.

Rehabilitation Work
With consent of Ministry of Environment, Lands and Parks to work in the stream outside of the accepted work window, the debris jam was removed in March 2000. An attempt to remove the debris jam in early December 1999 was aborted because of high water levels from a rain on snow event. March 2000 flows were groundwater dominated.

Dennis Creek was dewatered using two 4–inch trash pumps which discharged water back to the channel below the work site. In consultation with the Ministry of Environment, Lands and Parks, a commitment was made to flush the work site of sediment prior to restoring full flows. Once the debris jam was removed with a Hitachi EX200 excavator, an amount of streamflow was allowed into the work site to flush loose sediment to a temporary catchment dam. The flow was then cut off and the sediment behind the dam removed. Flows were re–introduced after the temporary dam (three courses of tied sand bags) had been removed.

Spoils were placed in a stable and passable configuration above the work site on Road 117. Cross ditches were installed above and a silt fence installed below the spoil pile to prevent erosion of sediment to the stream.

Cost Summary

Prescriptions	$ 488
Supervision	957
Equipment and Labour	3,237
Materials	215
Rentals (pumps, misc. tools)	1,133
Miscellaneous (helicopter)	525
Total Cost	$6,555

Outputs

Debris jam removal of approximately 100 m^3 of sediment and logs decreased the risk of water quality and fish habitat degradation (Fig. 8–5).

Production Estimates

Fish passage beyond the work site is possible at high and medium flows.

Proposed Work

Effectiveness monitoring will occur as part of ongoing deactivation in this key, target watershed.

All non–status roads in the community watershed will be surveyed to document previously unknown sediment sources.

For Further Information

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Figure 8–4. Upstream view of the debris dam on Dennis Creek. Dennis Creek is a sub–basin of Penticton Community Watershed.

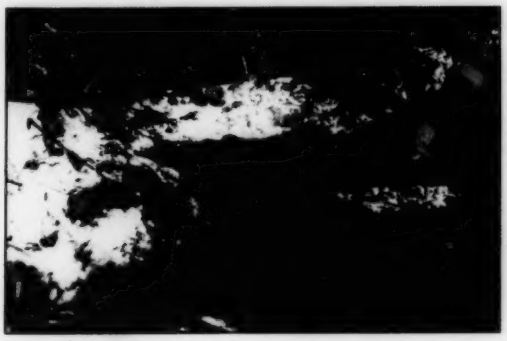

Figure 8–5. Completed works.

SOLCO LAKE RAINBOW TROUT SPAWNING CHANNEL

Objectives
Solco Lake Rainbow Trout Spawning Channel was built to eliminate sediment delivery, restore riparian function and restore rainbow trout spawning habitat immediately adjacent to Solco Lake.

FRBC Region/MELP Region/MOF Region
Thompson–Okanagan/Southern Interior/Kamloops

Authors
Stephen Jones, R.P.F. Southern Interior Forestcraft Ltd., Consultant to Weyerhaeuser

Proponent/Implementing Partners
Weyerhaeuser Company Limited, Okanagan Falls Unit.

Watershed/Stream
Okanagan Basin, Vaseux Creek Watershed, Solco Creek sub–basin, unmapped S4 tributary to Solco Lake

Location
Site is approximately 18 km southeast of Penticton near Okanagan Falls, BC. From 0 km on R201 (behind the Okanagan Falls sawmill), travel to 17.25 km, turn right onto Tuzo Road, travel to 27.5 km, turn right at the first access sign to Solco Lake (*a.k.a.* Fish Lake). Travel about 1.5 km and take the second left. Site is located behind a campsite.

Introduction
On the east side of Okanagan Valley, Vaseux's seven sub–basins (Vaseux, Dutton, Underdown, Solco, Venner, McIntyre and Wabash) drain 292 km^2 of the Okanagan Highlands region. The watershed rises from 325 m elevation at the confluence with the Okanagan River to 2335 m at the peak of Baldy Mountain.

Solco Lake is headwaters for the Solco Creek sub–basin and is a significant recreational site within Tree Farm License 15. Native and stocked rainbow trout populations sustain moderate to heavy fishing effort facilitated by the Solco Lake Forest Service Recreation Site (Rec site). The instream works are located near the confluence of the S4 stream and Solco Lake.

Assessments and Prescriptions
Past road construction (*circa* 1970) to the Rec site had crossed a small, unmapped S4 creek without using a ford. Over 30 years, the crossing and adjacent riparian cover had been severely degraded by recreational road users. Periodic improvements, including culvert installation, did not prevent ongoing damage to the stream or the introduction of sediment to Solco Lake.

Prescriptions and site plans to restore the channel and riparian zone were completed by Summit Environmental Consultants Ltd.

Rehabilitation Work
Prior to instream rehabilitation, the northerly road access was recontoured as part of an unrelated Rec site rehabilitation project. This eliminated future impacts from vehicles accessing the site from the north. Once channel restoration was finished, the southern access was blocked with a berm of large boulders, soil and logs and the remaining road fragment turned into a formal campsite (also part of the Rec site project).

A meandering 37 m long section of S4 channel was then reconstructed by building a new channel 0.7 m deep and 1.3 m wide. V–shaped log weirs, 0.2 m plunge pools, spawning gravel and riparian vegetation was added to provide spawning habitat and riparian function.

After establishing survey benchmarks and staking final channel elevations, the banks were shaped by backfilling the old ditchline with local and imported material and forming the banks with large riprap. V–shaped log weirs were installed below the level of the new channel bed as reconstruction proceeded. Considerable effort was required to complete all components of the reconstruction in a single excavator pass from back to front. This was required due to restricted work space from adjacent old growth.

As structures were installed, the new riparian area was planted with scoops of vegetation from adjacent understorey. Also, 2 m lengths of willow cuttings were machine planted along the new riparian zone into the water table.

The new channel was then capped with a 10–20 cm layer of washed, spawning gravel 1.9–5.0 cm in diameter.

Stumps and large woody debris were then placed instream for security cover. Pole sized immature conifers were placed across the stream to provide additional security cover.

Structures were inspected after the 2000 freshet and were functioning as planned. Willow survival is high but height growth is low. Height growth is anticipated to accelerate once root systems have expanded.

Cost Summary

Prescriptions	$1,187
Supervision	640
Equipment and Labour	3,857
Materials	198
Rentals (pumps, misc. tools)	300
Total Cost	$6,182

Outputs

This project restored approximately 55 m^2 of rainbow trout habitat by reconstructing channel and spawning habitat (Fig. 8–6). Natural recovery of riparian function was also initiated by willow planting.

Production Estimates

This project will supplement existing spawning habitat in Solco Lake.

Proposed Work

Effectiveness monitoring will occur as part of ongoing deactivation in this watershed.

For Further Information

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Figure 8–6. Upstream view of completed restoration.

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